CHYMICAL CATECHISM:

APPLICATION OF CHYMISTRY TO THE ARTS,

FOR THE USE OF

YOUNG PEOPLE, ARTISTS, TRADESMEN,

AND THE

AMUSEMENT OF LEISURE HOURS.

TO WHICH ARE ADDED

A VOCABULARY OF CHYMICAL TERMS, SOME USEFUL TABLES,

AND

A VARIETY OF AMUSING EXPERIMENTS.

BY S. PARKES,

MANUFACTURING CHYMIST.

"*Tout homme que reçoit une education libérale, compte aujourd'hui la chimie parmi les objets les plus indispensables de ses études.*" FOURCROY.

THIS EDITION IS EMBELLISHED WITH A FRONTISPIECE OF THE ECONOMICAL LABORATORY

OF JAMES WOODHOUSE, M.D.

Professor of Chymistry in the University of Pennsylvania, &c.

Philadelphia:

PRINTED AND SOLD BY JAMES HUMPHREYS,

ON CHANGE WALK,

Corner of Walnut and Second-streets.

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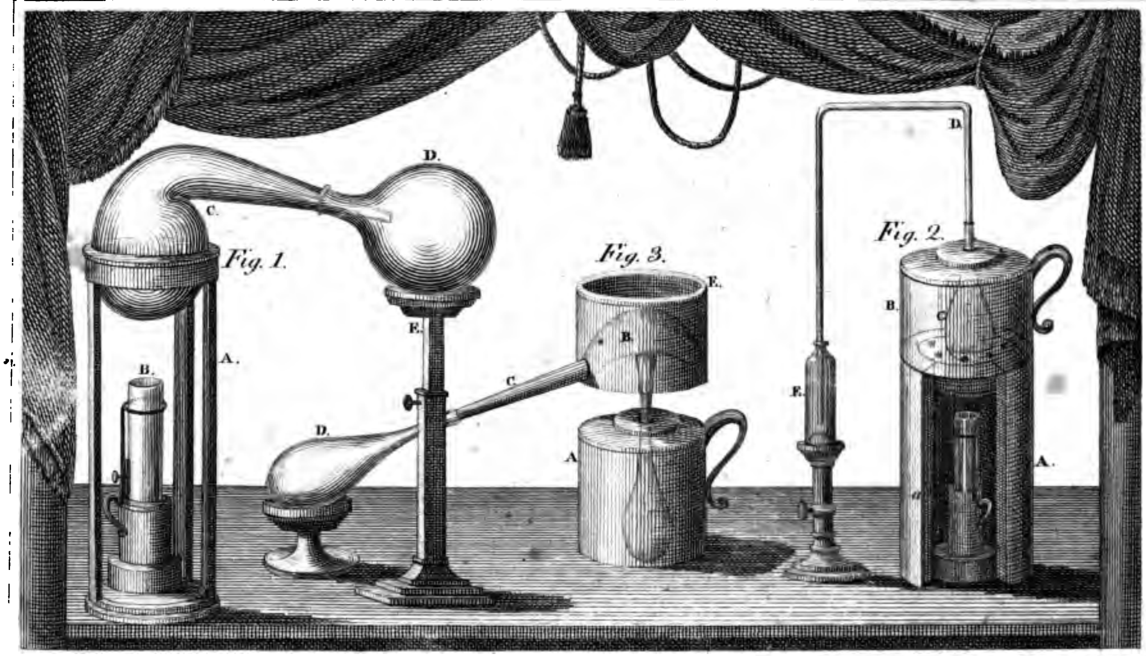

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Economical Laboratory, of James Woodhouse, M.D.

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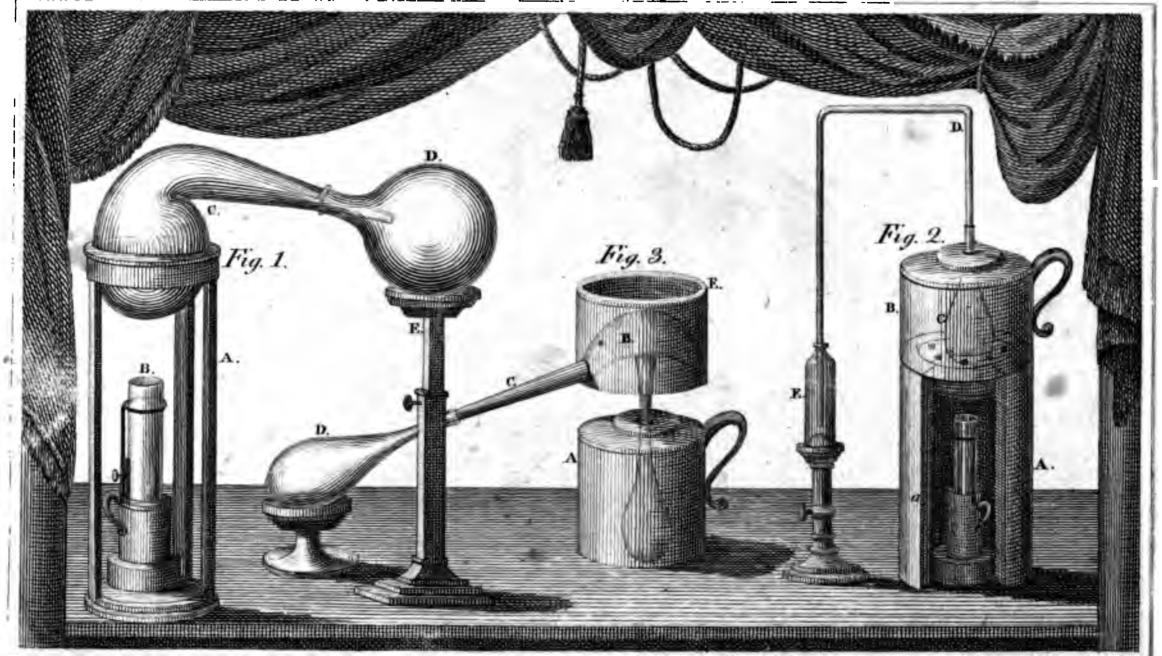

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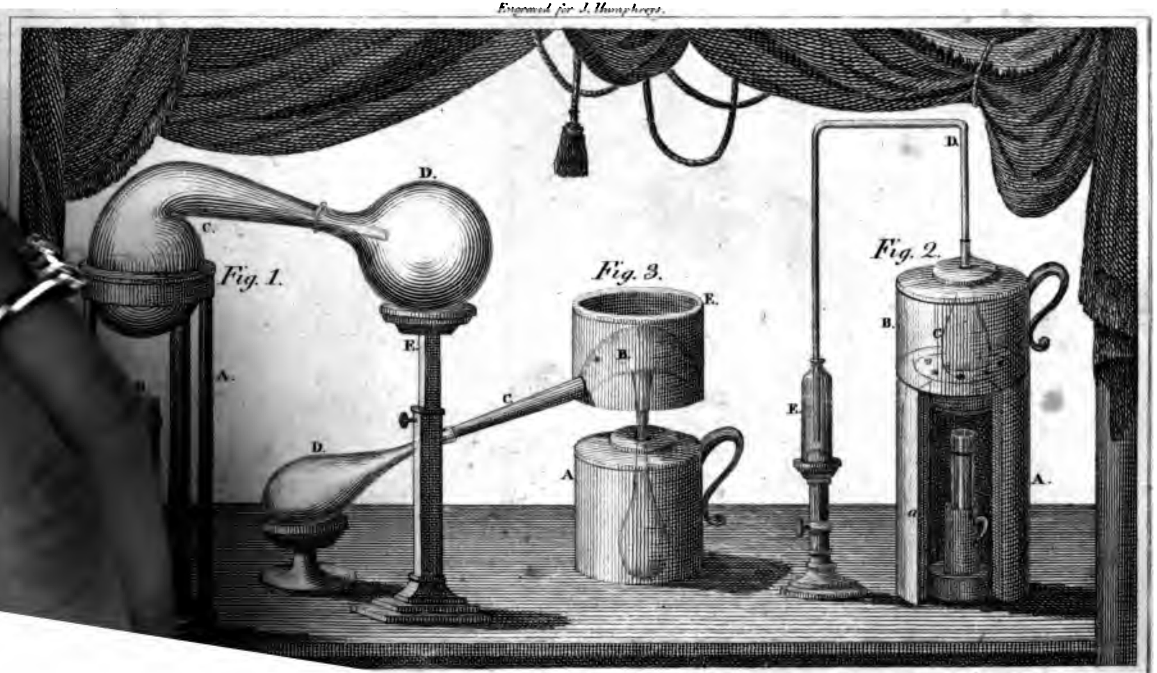

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PREFACE.

THE text of the following elementary treatise was undertaken without any view to publication, being intended by the author merely for the instruction of his only child. Finding, however, as he proceeded, that it would unavoidably attain a larger size than he had expected, and conceiving that its catechetical form gave it a simplicity and plainness not usually found in works of this nature, he was led to think of the propriety of publishing it. Other considerations then presented themselves; and, from a high opinion of the value of chymical knowledge, and the vast importance of inspiring a taste for it in early life, he imagined it might not be thought presumptuous, were he to give to the world what had cost him so much trouble to compile, and what he considered to be better calculated to teach the rudiments of the science to young people than any other book with which he was acquainted. Having endeavored to give the whole rather an inviting appearance than otherwise, even to youth, he presumed that such a performance might prove exceedingly useful in those seminaries where the preceptors have not had leisure or opportunity to study more elaborate treatises; and that it would also enable parents who are not qualified by previous acquirements to

instruct their children in the elements of chemistry, than which there can be nothing more essential, in whatever line of life a youth may be destined to move. But a more powerful motive was the desire to exhibit, in a popular form, a body of the most incontrovertible evidence of the wisdom and beneficence of the Deity in the establishment and modification of those laws of matter which are infinitely and beautifully varied, and whose operation is too delicate to be the object of general notice. For if it could be proved to the satisfaction of youth, that matter is subject to a vast variety of laws which escape common observance; and that, in the adjustment of those laws, the most minute attention, if it may be so expressed, has been paid to our convenience and comfort—it was imagined such a detail would tend to make a more indelible impression on the young mind, than the display of the same goodness in the operation of causes which come under our daily notice and observation.

With these views he could not but entertain a favourable opinion of the probable utility of a work upon such a plan, if properly executed. It was therefore with the utmost diffidence and anxiety that he ventured upon the task of preparing the following sheets for the press:—actuated, however, by the desire of being useful, he hopes that their imperfections will not expose him to unmerited reprehension. A work of this nature, particularly where such a mass of facts is crowded into one single volume, must be liable to errors and imperfections; but as he has chosen a new path, the allowance due to the defects of a first attempt will not, he confidently trusts, be refused him, especially by those who are aware of the labour and of the difficulties which attend the compilation of an elementary treatise.

In order to render the generality of parents and preceptors more competent to explain and expatiate upon the variety of facts which this science presents, and to qualify them in some measure to afford such answers to a number of questions which the young pupil, as he advances and becomes more interested in the experiments, will not fail to demand, the author has added a variety of explanatory notes. Many of these notes will be found to contain new matter, or, at least, what is not generally known or published; others, and perhaps the majority, were drawn from various sources: but as many were quoted from memory, and still more

from the common-place-book of the compiler, he was compelled in some instances, either to omit the authorities, or entirely forgo the advantages he had derived from the works, experiments, and opinions of some of the most enlightened chymical philosophers of the age. Here he has constantly been guided by one rule—to produce rather what is useful than original.

The author is not without his apprehensions lest some of the very numerous facts so interesting to young people, notwithstanding his best endeavours, should have escaped his notice; and in this instance he particularly begs for indulgence, as the greater part of his time is devoted to those occupations which are inseparable from the superintendance of a chymical manufactory. However, should the work attain a second edition, he will gratefully receive, and gladly avail himself of, any suggestions that shall be offered.

The moral reflections, which frequently occur, will probably be regarded by some as irrelevant to the subject; but, in compiling any initiatory book, no writer, as a parent, could lose sight of what is certainly a more important object than chymical instruction; viz. the necessity to embrace every favorable opportunity of infusing such principles into the youthful mind, as might defend it against immorality, irreligion, and scepticism.

The arrangement of the chapters, the order of the matter, and indeed, the whole plan may also seem to require an apology, especially to those who may perceive that the disposition of the subjects is different from that of every other chymical writer; but it is hoped that the reader will be satisfied with the assurance, that this method of distribution was not adopted but upon the most mature deliberation, and that the author had no object in view but to afford to the student a greater facility in the acquisition of chymical knowledge; being persuaded that a strict regularity of classification cannot always be so practical, or so well understood, in this and in many other branches of science, until the young mind be first prepared by the acquirement of the more easy and obvious truths. In chymistry, and in many other parts of philosophy, it were often better for the student to commence at once by experiments, and thence to advance to theory. Instances of the success derived from this mode are not wanting; nay, they are even numerous. Doctor Priestly is a very striking

example; nor should a Black, a Cavendish, or a Lavoisier be omitted; the last of whom certainly founded his well digested theory upon the results of many previous experiments.

Upon the whole, then, the proficient must not expect to find either a new or complete system of chymistry detailed in these pages: for if the rudiments of the science be drawn in such form as to invite a youth to study larger and more extended works*, and prepare him to imbibe only that theory which he can substantiate by his own experiments, the chief design of the author will then be fully accomplished.

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AN ADDRESS TO PARENTS.

AS soon as children begin to talk freely, they discover a desire to know every thing around them, and to be acquainted with the *cause* of every effect which arises in their presence. Curiosity and a thirst for knowledge seem to be natural to man. The great art of EARLY education, then, consists in supplying this curiosity with such a series of gratifications as is calculated to keep the principle alive, and to deposite at the same time those seeds which cannot fail to produce useful and valuable fruit in future life.

If the child have the usual activity of children, *curiosity* will be found to be the prominent feature, and if the Parent do not bestrew his path with innoxious flowers, he will not fail to find something to strike his fancy, among the destructive allurements which every where surround him.

Aware of this propensity, and of the necessity of providing in infancy some sort of employment for the youthful mind, many judicious parents have endeavoured at this period to select for their children such amusements and conversations as are directed *solely* to the discipline of the *heart* and of the *affections*.

Highly as I respect and applaud such motives, I cannot but be of opinion that at a *very early* age something likewise may be done towards cultivating the *Understanding*; and that, while the heart is moulding to every thing which is amiable and lovely, an hour or two may be employed each day, in laying a foundation for a superstructure of useful knowledge, without overburdening the youthful mind, or producing that distaste for books whi

some parents are apprehensive would be the consequence of an early attention to them.

Every man of reflection must be convinced of the importance of *œconomising* time even in childhood; for whatever useful knowledge can be communicated in infancy is clear gain, and will allow so much the more time in future for further acquisitions. If youth are designed to move in the active scenes of life, they will have but little time in the previous years for the attainment of those various branches of knowledge, which are necessary to make them valuable and respectable characters. Surely then the parents of such youth ought to embrace every opportunity of imparting whatever the child will receive with pleasure, and retain with profit. But here it cannot be denied that great circumspection is necessary, that *variety and amusement* may be united with instruction; and that the interference of the parent may always act in subservience to the curiosity of the pupil. To this end every toy may be made the vehicle of some useful truth, or used to illustrate certain known principles in mechanics or philosophy. And knowledge thus acquired will not easily be obliterated.

Parents who *see* the advantages of laying an *early* foundation for a liberal education, will doubtless make choice of different sciences to begin with, according to their own views of the importance of each; and books may be found on most subjects suitable to their purpose. For my own part, I should perfer *Chymistry*, in the *first* instance; this I should do on many accounts. Having observed that few people make any *proficiency* in the knowledge of Chymistry, who have not acquired a taste for it in *early* life; and conceiving that very many advantages arise from a general diffusion of this knowledge; I would endeavour to impart it in such a way that its elementary doetrines should become *perfectly familiar*, and be always at hand to explain the variety of *natural occurrences*, which are ever presenting themselves to an observant mind. To effect this *it must be taught early*, and with the utmost plainness; though I know of no book on the subject which is adapted to the capacity of children, or which a Parent, who is unacquainted with the science can make use of in instructing his child.

From the present state of our chymical knowledge, and the improvements which are daily making in our arts and manufactures by the application of its principles, it is become *absolutely necessary* to make chymistry a part of the education of every youth who is designed for a Manufacturing Trade, or who is likely to figure in the *higher ranks of life*.

And this may be effected much easier than will at first be imagined: for the chymical changes which are produced on substances

submitted to experiment are calculated to engage the attention, and to impress the memory, by the gratification of that love of novelty which is common to youth.

To this end all that is necessary, is a short, plain, elementary work, rendered interesting by a set of simple and striking experiments. This I have endeavoured to furnish in the following pages, and judicious parents and preceptors may add much to their value by the addition of many experiments which their own reading and reflection will suggest.

But as some persons may not be apprised of the *value* of chymical knowledge, it may be necessary to enumerate a few of the advantages which arise from its acquisition; for, in order to induce that general attention to the science which it deserves, *its utility* must be demonstrated:

It would be no difficult matter to show that the world might derive great advantages *even* from the diffusion of a *theoretical* knowledge of philosophy and chymistry. An instance or two will place this assertion in a clear point of view. Two thousand years ago, Archimedes was ridiculed for his attention to mathematics and the abstruse sciences; yet, owing to this knowledge, he was enabled to invent such mechanical engines as were sufficient to resist the whole Roman army. And such a dread had the soldiers of this man's knowledge, that if a rope only were hung down the walls of the city of Syracuse, the whole army would retire from before it in the utmost consternation.

A further proof of the importance of the dissemination of chymical knowledge may be taken from the construction of the *Steam Engine;* Mr. Watt having often acknowledged that his *first* ideas on this subject were acquired by his attendance on Dr. Black's *Chymical* Lectures, and from the consideration of his theory of latent heat and the expansibility of steam*.

The well informed people of France are *so satisfied* of the importance of chymical knowledge, that chymistry is *already* become an essential part of education in their public schools. It shall be my business in this place to endeavour to demonstrate, that it is of *equal* importance to the various classes of *our* community that the science should be cultivated with the *same* ardour in *these Kingdoms.* The science that we are recommending to your regards, has for its objects *every substance* of the material world, and is therefore equally interesting to every civilized nation upon earth.

Is your son born to opulence,—is he the heir to an extensive domain; make him an analytical chymist, and you enable him to appreciate the *real value* of his estate, and to turn every acre of it

* Davy.

[illegible] Has he a barren tract of country, which has [illegible] from generation to generation, he will explore [illegible] for hidden treasures, and will probably not [illegible]. By *analysing* the minerals which he discovers, [illegible] can with facility and exactness what proportion of [illegible] contain, and which of them may be worked to profit. [illegible] will operate on sure grounds, and will be prevented from [illegible] in expensive and unprofitable undertakings.

[illegible]istry will teach him also how *to improve* the *cultivated* parts [illegible] estate; and, by transporting and transposing the different [illegible], how each may be rendered more productive. The analysis of the soils will be followed by that of the waters which rise upon, or flow through, them; by which means he will discover which are proper for irrigation; a practice, the value of which is sufficiently known to every good agriculturist.

Will he *occupy* his *own estate*, and become the cultivator of his own land; he must of necessity be a chymist, before he can be an *œconomical* farmer. It will be his concern not only to analyse the soils on the different parts of his farm, but the peat, the marl, the lime, and the other manures must be subjected to experiment, before he can avail himself of the advantages which might be derived from them, or before he can be certain of producing any particular effect. The necessity of analysis to the farmer is evident, from a knowledge of the circumstance, that some kind of lime is *injurious* to land, and would render land hitherto fertile actually sterile. Besides, a knowledge of the first principles of chymistry will teach him when to use lime *hot* from the kiln, and when *slacked;* how to promote the putrefactive process in his composts, and at what period to check it, so as to prevent the fertilizing particles becoming effete, and of little value. It will teach him moreover the difference in the properties of marl, lime, peat, dung, mud, ashes, alkaline salt, soap waste, sea water, &c. &c. and, consequently, which are most suitable for the different kinds of land. A knowledge of the *chymical* properties of bodies will thus give a *new* character to the agriculturist, and render his employment rational and respectable*.

Are you a Practitioner of MEDICINE, and have acquired great and deserved reputation in your profession,—if you are not a chymist, you must recollect many painful disappointments, and must have witnessed very unexpected results from the effects of

* Lavoisier cultivated 240 acres of land in La Vendee, on chymical principles, in order to set a good example to the farmers; and his mode of culture was attended with so much success, that he obtained a third more of crop than was obtained by the usual method, and in nine years his annual produce was doubled. Laland's Life of Lavoisier.

medicine, when you have administered two or more powerful remedies in conjunction. A slight knowledge of chymistry would have informed you, that many of the formulæ in the Pharmacopeia, which are salutary and efficacious, are rendered totally otherwise, if given with certain other medicines,—not to say often destructive. Many instances of these chymical changes might be adduced, but one will suffice. Mercury and oxymuriatic acid have both been administered by medical men, and, *separately*, either of them may be taken without any injury to the animal œconomy; but if a physician, ignorant of the chymical operation of bodies on each other, should give these substances *in conjunction*, the most dreadful consequences might ensue, as oxymuriate of mercury is a most corrosive poison.

Does your son wish to follow your profession, charge him, when he walks the hospitals, to pay particular attention to the Lectures on Chymistry, and to make himself master of the chymical affinities which subsist between the various articles of the Materia Medica*. This will inspire him with professional confidence; and he will be as sure of producing any particular chymical effect upon his patient as he would if he were operating in his own laboratory. Besides, the human body is itself a laboratory, in which, by the varied functions of secretion, absorption, &c. composition, and decomposition, are perpetually going on; how, therefore, could he expect to understand the animal economy, if he were unacquainted with the effects which certain causes chymically produce? Every inspiration we take, and every pulse that vibrates within us, effects a *chymical* change upon the animal fluids, the nature of which requires the acuteness of a profound chymist to perceive and understand. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons, without the aid of chymistry†. Many thousand lives have been lost by poison, which might have been saved if the physician had been in

* Mr. Deyeux has shown, that even the preparation of plasters may be much improved by chymistry. His ingenious paper in the 97th number of the Annales de Chimie, contains much curious matter, well worth the perusal of medical men.

† All *animal* and *vegetable* poisons destroy by deoxidizing the blood. Substances which contain a large portion of oxygen are the real antidotes to *such* poisons. On the contrary *metallic* poisons are baneful in consequence of the oxygen they contain. Metals are devoid of activity in a metallic state, but when converted into oxides they become poisonous and corrosive, according to the portion of oxigen combined with them. Thus the grey and the white oxides of mercury are only purgative or alterative; while the red oxide is a corrosive poison. Decoctions of bark, having a great affinity for oxygen, have been given to counteract an over dose of antimonial powder, and have produced the desired effect.—*Fourcroy.*

which he may now acquire by a cul- ... And, though the operation of many ... be in these days well understood, ... of chymistry can enable the practitioner ... will counteract their baneful

... of the kingdom, there is ... not depend upon chymical ... for its successful ... the connexion which sub- ... will be necessary to take a ... are carried on in these.

... is the manufacture of ... the smelting of the ore to the ... operation is the effect of chy- ... it requires no small share of ... to appreciate the *value* of the ... for their reduction, which shall ... manner for facilitating their ... The subsequent process to ... are entirely chymical, and will be

... the importance of chymical knowledge to ... more forcibly than a thousand arguments. ... in saving a valuable life, I feel great plea- ...

... apothecary, in one of the northern counties, hav- ... was seized with symptoms which convinced ... but not knowing what noxious matter he had ... analysing the remainder, no antidote could be ... up as lost. A physician had been called in, but ... nor his partner, could get any information by ... contents of the fatal bottle; though, I understand, ... and in great reputation in their profession. In this ... At last one of them recollected that a neigh- ... the reputation of being a good chymist. To him the ... the partner of the patient hastened, to get the dregs analysed, ... what ought to be administered. Fortunately, this gentleman had ... Book of Tests, which I had procured for his brother, ... sent to him but a very short time before. By this book ... to ascertain that the poison was oxide of antimony: and when ... informed of it, he recollected that antimonial wine had been ... some years before; and supposed that the porter must have ... without the dregs being properly washed out. When the nature ... was thus ascertained, the gentleman had no difficulty in direct- ... a proper antidote, which was administered immediately; ... unfortunate man was preserved; but, in consequence of ... elapsed previous to its exhibition, the poison had so far ... of the system as to deprive him of the use of a limb.

conducted to the best advantage *only* by those who have acquired a knowledge of the chymical changes which take place in these operations. The making of CAST STEEL, which has been kept so profound a secret, is now found to be a simple chymical process, and consists merely in imparting to the metal a portion of carbon, by means of fusing it in crucibles with carbonate of lime.

The manufacturers of *utensils*, *&c.* in cast iron (called IRON FOUNDERS) will also acquire some valuable information by the study of chymistry; as it will teach them how to mix the different kinds of metals; how to apportion the carbonaceous and calcareous matter; and how to reduce the *old* metal, which they often receive in exchange; many hundred tons of which are annually sent away as ballast for ships, for want of that *knowledge*, which would enable them to convert it into good saleable iron.

The WOOLLEN, the COTTON, and the CALICO manufactures are also become of great importance to these kingdoms. In order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, the variety, and the durability of their several colours. Now of all the arts, none are more dependent upon Chymistry than those of DYING and CALICO PRINTING. Every process is *chymical;* and not a colour can be imparted, but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them. It is surely then *evident* how valuable a chymical education must be to that youth who is designed for either of these trades, and how necessary is that portion of knowledge which shall enable him in a scientific manner to analyse his different materials, and to determine the kind and the quantity necessary for each process. After all, his colours will be liable to vary, if he do not take into the account, and calculate upon, the changes which take place in them by the absorption of oxygen. A knowledge of which, and of the different degrees of oxidizement, which the several dyes undergo, requires no small share of chymical skill; and yet this skill is absolutely necessary, to enable either the dyer or the calico printer to produce in all cases permanent colours of the shade which he intends. Moreover, these artists must be indebted to chymistry for any valuable knowledge which they may acquire of *the nature* of the articles they use in their several processes; not to say that they are wholly dependent upon this science, for the artificial production of their most valuable mordants, and for some of their most beautiful and brilliant colours.

The art of BLEACHING, which is so intimately connected with calico printing, has also received such great improvement from the science of chymistry, that no man is now capable of conducting it

possession of the knowledge which he may *now* acquire by a cultivation of chymical science. And, though the operation of many of the poisons upon the system be in these days well understood, nothing but a knowledge of chymistry can enable the practitioner to administer such medicines as will counteract their baneful effects*.

If we look to the MANUFACTURES of the kingdom, there i
scarcely one of any consequence, that does not depend upon ch
mistry, for its establishment, its improvement, or for its successf
and beneficial practice. In order to see the connexion which su
sists between chymistry and the arts, it will be necessary to tak
short view of the principal trades which are carried on in th
kingdoms.

One of the staple trades of the country is the manufactu
iron; and it will be found, that from the smelting of the ore t
conversion of it into steel, every operation is the effect of
mical affinities. In the first place, it requires no small sk
chymical knowledge to be able to appreciate the *value*
different ores, or to erect furnaces for their reduction, whi
be contrived in the best possible manner for facilitatin
fusion, and for producing good pigs. The subsequent p
convert it into malleable iron, are entirely chymical, an

* The following fact will show the importance of chymical k
every practitioner in medicine more forcibly than a thousan
Having myself been instrumental in saving a valuable life, I f
sure in relating the circumstance.
About christmas last an apothecary, in one of the northern
...unk some bottled porter, was seized with symptoms w
...poisoned; but not knowing wh...
... of analysing the ...

to the best advantage without a knowledge of the *principles* on which the present practice is established.

The manufactures of EARTHEN WARE and PORCELAIN, which were so much improved and extended by the industrious and ingenious Wedgewood, and which are become by his means a source of national wealth, and give employment to thousands of the community, are dependent upon chymistry for the successful management of all their branches, from the mixture of the materials which form the body of the ware, to the production of those brilliant colours which give a value to the manufactures by their permanency and beauty.

Mr. Wedgewood was so sensible of the importance of chymistry to these arts, that he not only applied to the study of the science himself, but upon the death of the celebrated Dr. Lewis (author of the Commercium Philosophico-Technicum) he actually engaged his assistant, a Mr. Chisolme, to experimentalize with him, and to devote *his whole time* to the improvement of the manufacture by the application of his chymical knowledge, of which perhaps few men in the kingdom *at that time* had a larger share. A faint idea of the advantages which he derived from these sources may be conceived from the following circumstance. Dr. Bancroft in his Philosophy of permanent colours, when treating on iron, says, "I remember having been told, by Mr. Wedgewood, that nearly all the fine diversified colours applied to his pottery were produced only by the oxides of this single metal." This *one fact* is sufficient to show with what assiduous application he must have studied chymical science, and how insufficient every attempt to bring his manufacture to the perfection which it has now attained, would have been, *without* this attention.

The sister art of making GLASS is also entirely chymical, consisting in the fusion of siliceous earth with the oxides of lead and alkali. In this trade, as well as in many others, the *chymical* manufacturer, and the man of enlightened experience, will have many advantages. He will not only know how to analyse his alkalies and to ascertain their exact value before he purchases, but he will be enabled, on chymical principles, to ascertain the exact *quantity* necessary for any fixed portion of silex, which with others must always in the first instances be a matter of uncertainty, and must repeatedly subject them to losses and disappointment.

The TANNING OF HIDES is a process which was formerly carried on by persons who merely followed a routine of operations to which they had been accustomed without knowing the real cause of any of the changes produced on these substances. This art, which consists in impregnating the animal matter with a peculiar principle taken from the vegetable kingdom, which enables it to

resist moisture, and gives it great strength and firmness, has been well explained by Mr. Seguin. According to him, the gallic acid of the bark deoxidizes the skin, and as the skin loses its oxygen the tan combines with it, and forms it into leather*. It is now known, that many substances, besides oak bark, contain tan, and to modern chymistry we are indebted for the means of discovering with accuracy the *quantity* of tan which the several astringent vegetables contain. The arts will owe a further obligation to this science whenever it shall lead the way to the discovery of a cheap substitute for oak bark. At present the demand is so great that it is not only imported from the continent, but trees are cut down in this country *on purpose for the bark*, which are of no other use whatever. Should the chymical tanner not be fortunate enough to make a discovery of the kind just mentioned, he will at least be able to analyse the substances now in use, and to appreciate their *relative* value; a matter of no small moment to a man who operates upon a large scale†.

The manufacture of SOAP, a trade of considerable importance, and which materially aids the revenue of the country, has in general been conducted, like many of the foregoing, without any regard to system; and yet, perhaps, there is no art which may be benefitted in such *various* ways by chymistry as this. To those who are designed for this trade I have no hesitation in recommending the study of the science as a matter of the *first* importance. Many thousands per annum, which are now lost to the community, would be saved, if the trade was in general carried on upon scientifick principles. Make a soap boiler a good chymist and you teach him how to analyse barilla, kelp, potash, &c. so as to ascertain the *proportion* of alkali in each, and which is the most advantageous for him to purchase; a matter of mere guess with the common manufacturer. When these articles are at an exorbitant price, he will have recourse to various residuums, which he will decompose *by chymical means*, and make use of as *substitutes*. He will learn, in choosing his tallows, how to avoid those which contain a large portion of sebacic acid, which require much *more* barilla than good tallow, and yet produce *less* soap. He will know how to oxidize the common oils and oil dregs, so as to give them consistence, and render them good *substitutes* for tallow. He will know how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. He

* See his "Report to the Committee of Public Safety, on the new Methods of Tanning." It is printed in Annales de Chimie, tom. 20, 15. See also Mr. Davy's Paper on this subject, in the Philos. Trans. vol. 93, 233.

† Davy.

will be aware of the advantage which may be derived from oxygenating the soap while boiling; a knowledge of the chymical affinities will teach him how, at a cheap rate, to make as good and *as firm* soap with *potash*, as with the mineral alkali; and how to take up the heterogeneous salts so as to give the alkali full opportunity of forming a chymical combination with the oils, tallows, &c. And lastly, he will know how to make use of the *waste* lies so as to decompose the salts which they contain, and convert them to good and serviceable alkali, to be used in future operations.

The manufacture of CANDLES, which is frequently connected with the foregoing, though it is of comparatively small importance, may yet derive advantages from chymistry, which would repay the study. *Foreign* tallows, which frequently contain a large portion of acid, rendering them inferior to the English, may be purified at the most insignificant expense, by chymical means; and by the proper application of chymical agents, other brown tallows may be rendered beautifully white, and fit for the best purposes.

Where great quantities of candles are used, as in large manufactories, mines, collieries, &c, a great saving would arise from the use of carbureted hydrogen gas, which produces a beautiful intense light, much more cleanly than oil or tallow, and at little or no expense. A slight knowledge of the mode of managing the gases, would enable the proprietor of collieries to procure this gas from the small coal, which is *trodden under-foot*, and to light up his coal pits with it with the greatest safety, and at NO EXPENSE. If this mode were adopted the workmen would be lighted *much better* than they can possibly be by any other means; many thousand pounds would be annually saved to the community; and the many tons of tallow which are now consuming in these subterranean works, might be used in the manufacture of soap, which would tend to lower the price of that necessary article, and render our poor more wholesome and comfortable.

The BREWING OF FERMENTED LIQUORS, which is a trade of considerable consequence in the metropolis, is a chymical process altogether. To those persons, whose concerns are so large that it would require a princely fortune to purchase *even the utensils*, it must surely be of the utmost importance to acquire some knowledge of the *principles* of bodies, and of the nature of those changes which take place in the materials upon which they operate. I would therefore say to such persons, Give your sons a chymical education, and you will fit them for conducting, in the best possible manner, the business which you have established. Hence they will learn *how* the barley, in the first instance, is converted

to a sacharine substance by malting*; *how* the fermentative process converts the saccharine to a spirituous substance; and *how* the latter, by a continuation of the process, becomes changed into vinegar. The *nature* of fermentation (which till lately was entirely unknown) will be studied and understood; and they will not only have learnt the means of promoting and encouraging this process, but how to *retard* and *check* it, whenever it is likely to be carried too far; so that the scientifick brewer will be as sure of uniformly obtaining satisfactory results, as he would if he were operating on matter by mere mechanical means.

In like manner the DISTILLER; the maker of SWEET WINES; and the VINEGAR MANUFACTURER; will all receive benefit from the cultivation of the science we are recommending. Till the promulgation of the new chymical doctrines the making of vinegar was carried on like many *other* trades, in which the makers themselves had no idea of the nature of their own process. An acquaintance with chymistry will teach them many important matters; particularly, how it is that the spirituous fermentation is succeeded by the acetous; and how the liquor acquires the substance necessary to produce this change. When this is once known, they will soon find by experiment how to oxygenize their wash at the least expense, and in the least possible time. Indeed, when chymical knowledge is more advanced, the process which now takes several months will probably be completed in as many days.

The REFINING OF SUGAR is also a chymical process; every branch of which depends upon laws well known to chymists. The separation of the sugar from the molasses; the absorption of the superabundant acid; the granulation of the purified sugar; and the chrystallization of candy; will all be conducted most œconomically, and with the least difficulty, by those who have studied the science with a view to the improvement of their art.

The REFINING OF GOLD AND SILVER may appear to be merely a mechanical operation; but even in this trade the artist cannot produce a single effect which is not attributable to the play of the chymical affinities.

The manufacturers of ALUM; of COPPERAS; of BLUE VITRIOL; and of all other SALTS; would likewise do well to become chymists, before they attempt to bring their several arts to the perfection of which they are capable. The crystallization of salts depends upon so many adventitious circumstances, that no small share of knowledge is necessary to enable a manufacturer at all

* There is a valuable paper on this subject in the fifth vol. of the Memoirs of the Manchester Society, by Mr. Joseph Collier.

times, and in all seasons, to produce the article he intends. Till lately the MAKERS OF ALUM bought alkalies of every description. An accurate analysis of alum has *now* discovered, that potash and ammonia are the only alkalies which enter into the composition of alum; and consequently, that large sums have been expended by the manufacturer for an article of *no* use.

In like manner it might be shown, that the making of OIL OF VITRIOL, the REFINING OF SALT PETRE, and the MANUFACTURES OF PRUSSIAN BLUE, CUDBEAR, ARCHILL, and other colours, are all dependent upon chymistry for their improvement and successful practice:—but I flatter myself that the examples already adduced are sufficient to show that chymistry is *now* a necessary branch of the education of youth. Even the management of a GARDEN may receive improvement from a cultivation of this science.

The various operations of nature, and the changes which take place in the several substances around us, are so much better understood by an attention to the laws of chymistry, that in every walk of life the chymist has a manifest advantage over his illiterate neighbour. And it may be remarked, that in case of *failure* or disappointment in any particular line of commercial manufacture, the scientific chymist has resources as various as the productions of the country in which he lives, to which the uneducated man has no access.

Were parents *aware* of this truth, that sordid maxim *primo vivere, deinde philosophari*, would not be heard: but *every* youth would be instructed in the first principles of natural philosophy and chymistry, as the means of *qualifying him* for conducting the concerns with which he might be entrusted, to advantage. If "knowledge is power," surely the *love of knowledge*, and a taste for accurate investigation, is the most likely way for conducting to opulence, respectability, and rational enjoyment.

It has been objected to the teaching of chymistry to youth, that it is a science difficult to acquire; and that the *terms* are an insuperable bar to its early attainment; but I am of opinion, that the *elements* of chymical knowledge may be taught much earlier than is imagined by many who never made the attempt; and that, instead of any difficulty arising from the technical language of the science, the preceptor will find the new nomenclature a considerable auxiliary, greatly facilitating the communication and reception of its general doctrines*.

* Hear what one of the most celebrated French chymists says upon this subject. "I have," says he, "adopted the new nomenclature in my lectures and writings, and I have not failed to perceive, how very advantageous it is to the teacher; how much it relieves the memory; how greatly it tends to

Surely the terms oxygen, hydrogen, nitrogen, and caloric, may be learnt and retained with as much ease as adjective, participle, preposition, and interjection; independent of the perpetual connexion there is between the former and the several branches of the science; which circumstance soon renders all these terms extremely familiar.

The curious facts attending the vegetation of plants, and the metamorphoses of insects, are very properly allowed to occupy the *earliest* attention of children; but are not *all* the wonders of nature adapted to make indelible impressions on the young mind*; and can you conceive of any thing so likely to rouse the curiosity, as those striking changes which substances undergo in a series of well chosen chymical experiments?

Moreover, it is universally allowed, that in education nothing is so difficult as to induce young people to exercise the faculty of *reflection*, though no habit can be more important, or more necessary to be induced early; especially as it is an operation of the mind which requires exertion, and which is tiresome even to adults, unless they have been early accustomed to it. Now what can be so likely to create this habit, as the unexpected little exhibitions with which a chymical parent may occasionally surprise his child? And besides, if the experiments be judiciously chosen, and are such as may be begun and finished in a short time, the youth will find himself so much interested, that *other* important habits will gradually be induced; especially the habit of *application*, without which all other acquirements will be of little value.

Should it be imagined that the chymical lessons and experiments *alone* will be insufficient to induce these habits, several auxiliaries may be found; such as an occasional exhibition of the mechanical powers; models of machinery; dissected maps; portraits of men eminent for virtue and talents; collections of ancient coins, minerals, and fossils; preserved insects; and botanical specimens; all, or part of which, with a small chymical apparatus, would surely afford an ample entertainment for those hours which are not occupied by boisterous sports, or athletic exercises.

This mode of employing the *first* years would have another advantage; it would in time entirely supersede the necessity of *small* toys, which give a frivolity to the mind, and at best can only afford a temporary gratification; so that *then* nothing would remain

produce a taste for chymistry; and with what facility and precision the ideas and principles concerning the nature of bodies, fix themselves in the minds of the auditors."—Chaptal.

* "In *children* there is an early tendency to contemplate the works of nature, and to inquire."—Lord Kaimes.

among the pupil's treasures, but such things as were calculated to impress some truth, or to promote health and vigour.

When these habits of reflection and application are in some measure acquired, it may perhaps be advisable to direct the attention to other subjects in conjunction with chymistry:—if so, short and detached conversations upon the motions of the heavenly bodies; or short readings in natural history* might occasionally be resorted to with great advantage; or the sexual system of plants might be explained, without any danger of overburdening the memory, or producing any inconvenience whatever. Innumerable opportunities will hence occur of pointing out, that the *variety* discoverable in the vegetable tribes, and in the arrangements to bring each to maturity, was designed to contribute to the convenience of man, and to promote the comfort and happiness of the inferior creation. A frequent attention to these subjects will *necessarily* and imperceptibly impress the young mind with the *assurance*, that the DEITY is *really* good, and that he has provided for the felicity of every the most minute and insignificant of his creatures. But when he comes to enter *fully* into the science of chymistry, and to observe the infinite *variety* of contrivance to effect the designs of the Creator, and which will *obtrude* themselves upon him on every side, he will be lost in astonishment, and will often give vent to his feelings in artless expressions of gratitude and admiration.

With a mind previously prepared to attribute every effect to the contrivance of a BEING, whose consummate wisdom is never exercised but in conjunction with infinite *goodness*, he will enter upon the study of chymistry with *peculiar* advantage; at every step some new beauty will discover itself to his enraptured mind, and while the several substances collected for experiment are undergoing changes as astonishing as various, in the hands of his preceptor, his attention will be engrossed, not only in consequence of the amusement which these little manipulations afford him, but by the beautiful simplicity and permanency of those laws by which the several affinities are regulated and directed. The beneficial and salutary tendency of *several* of these arrangements will soon become more and more apparent; and if some favourable opportunities be embraced of pointing out what would have been

* Natural history is *intimately* connected with chymistry, as it *must* depend upon this science for any elucidation of the minute properties of those substances, the outward characters of which it describes; so that what Mr. Dayes has said of the painter, may, with greater truth, be said of the chymist. "The volume of NATURE is laid open to him: his attention is directed to the vast and to the minute; and his imagination clings to perfection with ineffable delight."

the consequences of *a different* constitution of things, such indelible impressions in favour of goodness and beneficence will be made upon the young mind, as cannot fail to have a happy influence in forming the character, and meliorating the heart.

Moreover, it is the necessary consequence of an attention to this science, that it gives the habit of *investigation*, and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true, but what is the result of *experiment*, he will be in little danger of ever being led away by the insidious arts of sophistry, or of having his mind bewildered by fanaticism or superstition. The knowledge of *facts* is what he has been taught to esteem, and no reasoning, however specious, will ever induce him to receive as true what appears incongruous, or cannot be recommended by demonstration or analogy.

Having extended this address to a length which I did not intend, I have only to recommend it to *you*, who are parents, to consider the *importance* of an assiduous and *early* cultivation of the understanding.

If a proper attention has been paid *in infancy* to the regulation of the dispositions and affections, you will find your children tractable and docile. Economize then their time; husband well their early years; and, instead of driving them to servants for their amusements, let them *feel* that their curiosity is always best gratified by *you*, and that their *sweetest pleasures* are derived from an intercourse with you. With these feelings their confidence will be entire and unreserved; *to you* all the questions of an infantile curiosity will be addressed, and to *no other* will they ever think of looking either for information or reward. A wise parent then will not lose a moment of this inviting season, but will sedulously watch every opportunity of committing good seed to soil so well prepared for its reception. He may differ from the generality of mankind as to the *relative* importance which he attaches to different branches of knowledge; but which ever is thought to be most valuable, and best calculated for these early days, will surely be made choice of, and explained with perspicuity and kindness.

Were parents sufficiently sensible of the *importance* of the *first* years of life, and would, as early as possible, contribute to the utmost of their power to inform the mind, and humanize the heart, we might expect to have a *rational* system of education acted upon by the middling and higher ranks of life; the result of which would soon be perceptible in all classes of society. Our nobility would hence be entitled to all the respect which would necessarily attach to the liberal applications of large incomes to the promotion of the public good, and to the acquisition and promulgation of knowledge; our magistrates would be upright, humane, and intel-

ligent; our clergy would be the repositories of recondite erudition, and eminent examples of the effect of religion upon the character, when devested of all bigotry, mystery, and fanaticism; our merchants, manufacturers, and tradesmen, would be economical, industrious, enterprising, and ingenious; and our country gentlemen, "instead of giving themselves to the fowls of the air, and to the beast of the field," would be qualified to cultivate their estates upon scientific principles, and to enjoy their retirements with philosophic minds.

☞ *The Pupil is advised to go through the Catechetical Part of each Chapter before he attends to the Notes; for, as the Questions generally arise out of the preceding Answers, the connexion of the whole will be best perceived by this method, and will be most likely to be remembered.*

CHAPTER I.

INTRODUCTORY AND MISCELLANEOUS.

WHAT is Chymistry?

Chymistry* is the science which teaches the art of examining natural bodies, and of investigating their peculiar properties†.

How do chymists examine the properties of bodies?

The chymical examination of bodies is in general effected by producing a change‡ in the *nature* or *state* of the body under examination§.

* The *following* definitions of chymistry have been given by some of our best chymists. That in the text was chosen on account of its plainness, and because it was sufficiently concise to be committed to memory.

"Chymistry is the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts."—Dr. Black's Lectures, vol. 1, 12.

"Chymistry is that science which treats of those events or changes in natural bodies which are *not* accompanied by *sensible* motions."—Dr. Thomson, vol. 1. 3.

"Chymistry is a science by which we become acquainted with the *intimate* and *reciprocal* action of all the bodies in nature upon each other."—Fourcroy's General System of Chymical Knowledge.

† The basis of chymical science is the analytical examination of the works of nature, and the investigation of the properties and uses of the several substances with which we are acquainted: it should therefore be the *first* concern of every chymical student to receive nothing as *true* but what has actually been *proved* by experiment or analogy. Let him rely upon nothing but facts, and he will be in little danger of forming extravagant or erroneous opinions. If we "dare to investigate Nature, we must *see her* and *try her* on all sides, and be *sure* that she still confesses the same thing.

‡ This change is frequently effected by the addition of some *other* substance, which forms a combination with *a part* of the substance under examination, and leaves the other part in a detached state. On this principle re-agents, or chymical tests, are employed, the operation of which will be explained as we proceed.

§ To the *eye* many substances appear similar to other substances, though they possess different, and perhaps opposite, qualities; it therefore became

By what means do chymists effect a change in the qualities or states of natural bodies?

It is generally effected by means of *heat**, or by the *mixture*† of some other matter with the matter intended to be examined‡.

How does the application of heat and mixture enable chymists to examine the properties of bodies?

By these means chymists effect the *decomposition* of compound bodies, and thus acquire a knowledge of the *nature* of the ingredients of which they are composed§.

necessary to discover the means of analysing these substances, and of ascertaining wherein their difference consists. This we find in *chymical re-agents*.

It may be considered as an axiom in the science of which we are treating, that *whenever chymical action takes place, a real change is produced in the substance operated upon, and that its identity is destroyed*. An example will place this in a clear point of view. If a little whiting be put into a glass of water, the whiting will sink to the bottom of the vessel. Though it should be mixed with the water, if left at rest it will soon subside. No chymical action has taken place; therefore the water and the whiting both remain unaltered. But if a little whiting be put into a glass of diluted sulphuric acid, a violent effervescence will commence the moment they come in contact with each other; a chymical union of the two substances will be the consequence of this chymical action; the identity of each substance will be destroyed; and sulphate of lime (a body entirely different to either of the substances employed) will be produced.

* Heat has a tendency to separate the particles of *all* bodies from each other. Hence nothing more is necessary to effect the decomposition of many bodies than to apply heat to them, and to collect the substances which are separated by that means. The mixture of two or more compounds often produces a decomposition in each by means of chymical affinity, a *property* of bodies which will be more fully explained hereafter.

† It is owing to the laws of *affinity* that we are enabled to examine natural bodies by means of *re-agents*, or chymical tests. Some of these are simple, and act by *single* affinity; others, which are compound, act by producing a *double* decomposition.—See Chap. xiii.

‡ Some idea of this mode of examination may be given by the following experiment:—Take camphor, which is a solid substance, put it into a phial half filled with spirits of wine; in a short time the camphor will be dissolved in the fluid, and the spirit will be as transparent as at first. This solution is owing to the *affinity* which subsists between these two substances. If water be now added (which has a greater affinity for the spirit than the camphor has) the water will unite with the spirit, and the camphor will be precipitated. In this way the camphor may be nearly all recovered, as at first. By distillation the water may also be separated from the spirit, and exhibited in a separate state.

§ This is called analysis. It is distinguished by chymists into the *simple* and the *complicated* analysis. The former is effected whenever a body is so decomposed that its elements may be exhibited in a separate state, and by reuniting them the body may be reproduced. Where the elements of a body form new compounds during its decomposition, and cannot be reunited to
ce a similar substance to that which has been operated upon, it is an
f *complicated* analysis.
r to ascertain the exact nature of bodies, chymists have recourse to
s well as analysis. Whenever the component parts of any body are

What is meant by decomposition?

In chymical language decomposition means the act of dividing a body into its simple elements*. Thus water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

What are the different states of natural bodies?

All bodies are either solid†, liquid, or aëriform‡.

reunited in order to form a similar substance, and a similar substance is produced, the nature of that body is said to be proved by synthesis. When a body admits of being examined in both these ways, the result is very satisfactory.

The examination of those substances which we receive from the hand of nature, if conducted on these principles, may sometimes be tedious, but the consequences will be pleasing; the processes may be slow, but they will be sure; and the acquisition of truth, by patient investigation, and by means of our own exertion, affords to a cultivated mind the most delightful gratification.*

* Take sulphate of magnesia (Epsom salt) as an instance of the decomposition and re-formation of a substance by chymical means. Make a solution of this salt in hot water, and pour into it a little of a solution of carbonate of soda; the soda will precipitate a white powder, which, on examination will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda (Glauber's salts) will be found in the vessel. In this decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. In this way Epsom salt may be analysed, and proved to consist of sulphuric acid and magnesia.

In order to prove the composition of this salt by synthesis, dissolve magnesia in diluted sulphuric acid, saturate the liquor, and crystallize. Epsom salt will be the result.

It may be remarked, that chymists have not only the power of decomposing natural bodies, but of producing, by combination, various other substances, such as are not presented to us by the hand of Nature. Alcohol and ether are of this class.

† We have many reasons for believing the original particles of all matter to be impenetrably hard, both from experiment and the necessity of the case, —that nature might be incapable of wearing out. If water falls through a vacuum on metal, or on any hard body, it will strike it with as loud a noise as if one piece of iron fell upon another. A small instrument, which is sold by the mathematical instrument makers, called a *water hammer*, shows this very satisfactorily.—Mr. Walker.

The force of cohesion increases in a substance in proportion as its moleculæ are brought nearer together. Thus alumine, which has shrunk considerably in bulk, by being submitted to a high degree of heat, has not only experienced much mechanical cohesion, but has thereby acquired the power of resisting acids and alkalies.—Berthollet's Chymical Statics, vol. 1, 3.

‡ When attraction prevails in bodies they become solid; when caloric prevails they become gas: fluidity seems to be a medium between the two. The ultimate particles of matter existing in these separate states escape the cognizance of our senses. They are so infinitely small, as not only to escape the scrutiny of the highest magnifying powers in glasses, but even imag

What do you mean by a solid body?

Solidity is that quality of bodies whereby their parts cohere firmly, so as to resist impression*.

What are liquid substances?

Liquid substances are those whose parts do *not* cohere firmly, but have free motion among themselves†.

What occasions the difference in these bodies?

Liquid substances are nothing more than solids converted into

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tion itself is incapable of forming any idea of the size of an original particle of matter. When we have reduced matter to the most impalpable powder, we are far, very far, from the *atoms* which compose that powder. Musk, camphor, and several essences, will exhale for weeks, and throw off their particles to the distance of several yards, without losing any sensible weight.—(Mr. Walker's Lectures.) Even gold, when dissolved in aqua regia, assumes a gaseous state, with a small degree of heat. How minutely must the gold be divided by the acid, for its particles to exhale in atmospheric air!

A new theory, to account for the phenomena of matter, has been proposed by the celebrated Boscovich, and admitted by many philosophers. An account of this system may be seen in the Supplement to the Encyclopædia Britannica, under the article *Boscovich*.

* Sir Isaac Newton has said, that the primary particles of *all* bodies are *hard*, whether solid or fluid; and that if the particles be so disposed or fitted to each other as to touch in large surfaces, such body will be hard, otherwise it will be soft.

Perhaps it would be more philosophical to say, that when the *attraction of aggregation* is strong enough to resist the motion of the particles of a body among themselves, that body will be solid, otherwise it will be soft.

Mr. Lavoisier has explained solidity thus:—"The particles of all bodies (says he) may be considered as subject to the action of two opposite powers, repulsion and attraction, between which they remain in equilibrio. So long as the attractive force remains stronger, the body must continue in a state of *solidity*; but if, on the contrary, heat has so far removed these particles from each other as to place them beyond the sphere of attraction, they lose the cohesion they before had with each other, and the body ceases to be solid."

† We have no reason to suppose that fluidity is an essential property of any liquid substance whatever; but rather that solidity is the natural state of all bodies, for we are able to reduce most substances to a state of fluidity by the combination of caloric. In general, bodies treated in this way expand in all their dimensions, and the attraction of aggregation is so much weakened thereby, that the particles of the body slide over each other, and are put in motion by the slightest impulse. This is the only distinguishing character of fluidity that we are acquainted with.

On the contrary, the greatest number of liquid substances take a *solid* form by reduction of temperature. Thus water congeals, and forms ice. Even the gases show this disposition. The oxy-muriatic acid gas becomes concrete, and crystallizes at a temperature near to that at which water congeals. All the gaseous substances, when they have lost their elasticity by forming some combination, are disposed to assume the solid state, if the temperature allows it. Ammoniacal gas and carbonic acid gas become solid as soon as they enter into combination; and hydrogen gas, the most subtle of the ponderable elastic fluids, forms, with oxygen gas, the water which becomes ice.—Berthollet's Chymical Statics, vol. 1, 2.

liquids by heat*. A larger portion of the matter of heat would convert them into vapour.

What other name is given to liquids?

They are likewise called fluids: we call the air a fluid†.

Why is the air called a fluid?

Because it flows like a fluid‡, and light substances will swim in it.

* Fluidity is owing to the matter of heat being interposed between the particles of the fluid; which heat would dissipate all fluids into the air, were it not for the pressure of the atmosphere, and the mutual attraction which subsists between those particles. Was it not for this atmospheric pressure, water would not be known in any other states than those of ice and vapour; for, as soon as ice had acquired caloric enough to give it fluidity, it would begin to boil, and would be dispersed into the regions of space. This may be proved by direct experiment, as will be shown in the following chapter. The constitution of the world in this respect exhibits a beautiful instance of the harmony of nature, and of the exquisite contrivance of its divine Author.

On the other hand, could we *totally* abstract the matter of heat from any fluid, no doubt but that fluid would, by that mean, be changed to a solid; the lightest vapours being nothing more than *solids* combined with heat.

Not only fluids, but all those substances which are soft and ductile, owe these properties to the chymical combination of caloric. Metals owe their malleability and ductility to the same cause.

The following experiment will *prove*, that it is caloric which converts solids to fluids:—Expose a pound of water and a pound of ice, both at 32°, in a room, the temperature of which is above the freezing point. The water will arrive at the temperature of the room several hours before the ice is melted. The caloric, therefore, which has all the time been entering into the ice, but is not to be found in it by the thermometer, must have become *chymically* combined with it in order to give it fluidity. The caloric appears to be lost; its properties are merged in the fluid just as muriatic acid, by union with lime, loses all its characteristic properties—(Henry.) See this further explained in the chapter on caloric.

† Atmospheric air is one of the permanently elastic fluids. Steam is an *elastic* fluid, but atmospheric air in all states, and in all seasons, is *permanently* elastic. This elasticity arises from caloric being chymically combined with the solid substances of which it is composed. I say *solid*, because we have abundant evidence that oxygen and nitrogen are both capable of taking a solid form, and actually do, in many instances, exist in a state of solidity. Nitrogen is a component part of all animal substances, and exists in a solid state in all the ammoniacal salts Oxygen takes the same state when it combines with metals and other combustibles; and in the composition of the nitrous salts, they both take the same state of solidity. These facts surely evince that atmospheric air owes its fluidity to caloric.

One of the general laws discovered by Dr. Black, and which he laid down as a chymical axiom, was, that "whenever a body *changes* its state, it either combines with caloric, or separates from caloric." The great number of natural appearances which are explained by this general law, renders it important, and it ought to be remembered by all those who wish to make a progress in the science.

‡ The air is also known to be a fluid, by the easy conveyance which it affords to sound.

What
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W
I ... Thus a cork
bu
... *ubstances sinking and*

... ne other swims because

... *that a stone is heavier than*

... s often formed in the retorts and ... equent explosions, and sometimes ... by a torrent of atmospheric air ... not possess the common properties ... It is a property of fluids to press ... downwards; so does atmospheric air. ... the breakfast table, by placing a tea- ... forming him that it swims there because ... of water of its own bulk. Water may ... the tea-pot into the cup; and he may be ... sinks in the bason as it becomes loaded with ... of the water and the cup are too great for ... port, and the whole sinks.

... informed that it is on this principle that ... constructed, and that it is this property of fluids ... foreign countries, and bring our vessels back ... The wisdom and goodness of the Almighty ... ty to water, may be insisted upon with great ad- ... of some of the consequences which would have ... constitution of things, would furnish matter for ... versations.

... in a vessel is indicated by the depth to which the ... water. In canal boats this is shown by graduated brass ... the sides of them. An account of a curious method of ... tonnage of ships hydrostatically, may be seen in the first ... Retrospect. It is founded on the different draught which a ... in salt and in fresh water, owing to the different specific gravity ... fluids. That nautical men should be acquainted with this hy- ... axiom, is certainly of importance; for, should a captain load his ... a *full* cargo at any sea port, his vessel would inevitably sink ... into the Thames.

... questions in this *introductory* chapter may perhaps be ... insignificant; but the reader is requested to consider no- ... which can tend to lay a just and stable foundation for the ... interesting science. The generality of elementary wri- ... much when they suppose that what they omit is universally ... ings which they consider to be of public notoriety are known ... who have not paid a *particular* attention to the subject. ... ks which are called elementary, disappoint the expectation and are laid by with distaste, for want of the first rudiments being detailed with minuteness and simplicity.

Not that the stone is heavier * than the *whole* of the water in the vessel; for, if it be heavier than a portion of water of its own bulk, it will sink†.

What term is made use of to express the relative *weight of bodies?*

Specific gravity. Thus the specific gravity of one body may be much greater than that of another body, though their absolute weights may be the same‡.

How do you explain or account for the difference in the specific gravity of different bodies?

When a body is larger, or takes up more room than another body of the same weight, it is said to be specifically lighter than that body§.

* The pupil should be informed that *all* stones are not heavier than water, for that these natural bodies differ very much in specific gravity; that, though the specific gravity of sulphate of barytes is 4.40, or nearly 4½ times as heavy as an equal bulk of water, some species of the asbestus are lighter than water. Some kinds of pumice stone are also much lighter than that fluid.

† It is an axiom in hydrostatics, that every substance which *swims* on water, displaces so much of the water as is exactly equal to its own *weight*; whereas when a substance *sinks* in water, it displaces water equal to its bulk.

Take a piece of hard wood, balance it accurately in a pair of scales with water, and then place it gently on the surface of water in a vessel exactly filled with that fluid, and it will displace a portion of the water, which will flow over the top of the vessel. If the wood be now taken with care, it will be found that the water in the scale will exactly fill the vacancy left by the wood.

‡ The specific gravity of bodies is denoted in chymical writings by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Thus the specific gravity of the strongest sulphuric acid of commerce is said to be 1.900, or nine-tenths heavier than water. Iron is 7.650, or more than 7½ times heavier than water; that is, a square inch of iron, if put in a scale, would require 7½ inches of water to balance it; silver, 10.478; gold, 19.300; and platinum 23.000, or 23 times heavier than water. The specific gravity of bodies is noted in the same way throughout this work.

§ The nations of antiquity were unacquainted with any method of ascertaining the specific gravity of bodies. A singular event was the cause of its being discovered by Archimedes 200 years before Christ. Having reason to believe that an unprincipled goldsmith had greatly debased the golden crown of Hiero II. king of Syracuse, he was anxious to ascertain the fact; but was perplexed by not knowing how to effect it.

However, one day while bathing, the difference in the weight of his own body, when in the water and when out of it, gave him the idea that he might adopt *that* method for discovering the specific gravity of the king's crown; and it is related of him that he was so rejoiced at the discovery, that he leaped from the bath in an ecstasy, and ran naked about the streets of Syracuse crying, *I have found it! I have found it!* It would be a pleasing, and not altogether an unprofitable employment, to endeavour to recount the mathematical, philosophical, and chymical truths, that we are in possession of, which tend to promote the happiness and civilization of man, and which the antients were unacquainted with. In these *enlightened times* every youth

What definition do you give of the air which you spoke of in connexion with this subject?

The air is a very light fluid which surrounds* us every where; it is the medium in which we live, and without which we could not exist†.

What is the great body of this fluid called?

It is called the atmosphere‡.

You say the atmosphere is fluid; what proof have you of its being so?

Many instances might be adduced to show that the atmosphere is fluid, but the ascension of an air balloon is a sufficient proof of its fluidity§.

How do you account for an air balloon floating in the atmosphere‖?

Because it is filled with a gas which is specifically lighter than common air.

may find avocations suited to his taste, and even in his pleasures will be at no loss to select amusements which are both rational and respectable.

* If the earth had no atmosphere at the time of its formation, a chymist would have no difficulty in conceiving how an atmosphere might be produced by the decomposition of water and other substances, and that this might be effected by the agency of internal fires. I refer the reader desirous of investigating this subject to an interesting essay in the second chapter of Lavoisier's Chymical Elements.

† The Creator *knew* how necessary atmospheric air would be for the support of animal life; he has accordingly endowed it with the property of preserving its own equilibrium at all times, and in all places. Its elasticity is such, that however it may be consumed by respiration or combustion, its place is immediately supplied with a new portion; and though by a mistaken policy the doors and windows of our habitations may be constructed so as to exclude it as much as possible, it *will* have admission; it forces its way through every crevice, and performs the important office assigned it, in defiance of all our exertions. If the properties which are given to the different substances in nature, and the laws by which they are governed, be thus examined, we shall find them all tending to one point, viz. the welfare and felicity of every species of animated beings.

‡ This word is derived from the Greek language, and signifies a body of vapour in a spherical form. By this name we understand the entire mass of the air which encircles all parts of the terrestrial globe, which moves with it round the sun, which touches it in all its parts, ascending to the tops of its mountains, penetrating into its cavities, and incessantly floating on its waters. It is the fluid which we inhale from the first to the last moment of our existence. Fourcroy, vol. i. 207.

The blue colour of the sky is owing to the vapours which are perpetually rising from the earth and mixing with the air. This Saussure demonstrated by experiment on the Alps. Thomson, vol. iii. 298.

§ Atmospheric air, like all other elastic fluids, yields to the slightest impulse, and is put in motion with the greatest ease; but it has not the power of penetrating many substances, like oils and some other fluids.

The facility and rapidity of the motions of atmospheric air cannot be explained on any principle but its fluidity. Some of the winds move nearly at the rate of 4000 feet in a minute.

‖ This and the following question may appear to be an useless repetition of the doctrine taught in the first part of this chapter; but as innumerable

We have seen that cork swims on water, why does it not swim in air?

Because the air is specifically lighter than the cork*; that is, it is not dense enough to bear it†.

facts dependent on specific gravity are perpetually occurring in every department of chymistry, it was thought advisable thus *to vary* the question, in order to prevent a possibility of a young person committing this chapter to memory without thoroughly *understanding* what is so important to his future progress.

It is absolutely necessary for him to understand the nature of specific gravity to enable him to analyse minerals, to examine the gasses, and to perform a variety of other operations in chymistry. Besides, this knowledge will be of use in the common occurrences of life, and no one, who wishes to have a general acquaintance with things, ought to neglect to learn the methods of taking the specific gravity of bodies. For instance: suppose a person has a piece of silver plate, which he suspects is alloyed more than it ought to be, a knowledge of specific gravity, and of the principle of bodies which sink in fluids, displacing so much of the fluid as is equal to their bulk, will enable him to ascertain its value with accuracy. He has only to weigh it in air and then in water, and calculate from the difference in its weight when weighed in these two mediums. Thus, if it weighes 46 ounces in air, and only 41½ ounces when weighed in water, its bulk of water is 4½ ounces. Now if 46 be divided by 4½, the quotient will be 10¼; which shows, that the piece of plate is 10¼ times as heavy as its bulk of water, which is about the specific gravity of *standard* silver. *Pure* silver is 10½ times the specific gravity of water. For an account of the different methods of taking the specific gravity of different substances, see Additional Notes, No. 1.

* Poplar is the *lightest* wood we have next to cork, the specific gravity of which, according to Lavoisier, is .3830; but the specific gravity of cork is only .2400, water being 1.000.

Cork is the outward bark of a tree which grows wild in the southern [illegible] of Europe. When the tree is of a certain age it may be barked [illegible] eight years. It is heated and singed over a strong fire, and then [illegible] stones in order to be pressed straight. According to Pliny, cork [illegible] to the Romans, and was applied by them to as many purposes [illegible] sent. Xenophon relates, that the Roman ladies, who wished [illegible] placed several layers of cork within their shoes.—Beck[illegible] Inventions, vol. ii. 115.

Cork possesses very singular properties. It may be easily [illegible] recovers its elasticity as soon as the compressing power is [illegible] fore fills up every crevice of that space into which it has [illegible] It may easily be cut into any form; and though it [illegible] is the cause of its lightness, it suffers neither water nor [illegible] escape through it.—Beckmann's Hist. vol. ii. 114.

The use of cork, in preserving liquors, is well known. [illegible] safety jackets for the preservation of lives by sea [illegible] use in teaching the art of swimming. The epider[illegible] the same nature as cork.

† That one substance swims upon another in [illegible] density of the fluid which supports it, should be [illegible] hension of the pupil; for, till he thoroughly und[illegible] be impossible for him to comprehend the cau[illegible] will take place during the course of his exper[illegible]

When *this* is understood, it may be prop[illegible] tages which we derive from this property [illegible]

What is the specific gravity of atmospheric air?

A pint measure of atmospheric air weighs only eight grains; the same measure of pure water weighs one pound, avoirdupois*.

If the specific gravity of water be so much greater than that of atmospheric air, how is water retained in the atmosphere?

The water which is taken up by the atmosphere is not in an aqueous state, but is converted into vapour†, by the matter of heat‡.

How is it that heat converts water into vapour?

A large portion of the matter of heat combining chymically with water renders it specifically *lighter*; which is the cause of its rising in the air, and floating there§.

principle, the oxygen gas which is secreted by vegetables, is detained in the *lower* regions of the air, that it may combine with the nitrogen gas produced by animal respiration, to preserve the purity of the atmosphere;—that, owing to this, the carbonic acid gas, which is still heaver, and which is formed also by animal respiration and combustion, is confined within the reach of vegetables, which absorb it with avidity, and separate it into its original elements; —and that to this principle it is also attributable that the mephitic air arising from the crowded haunts of men, does not produce pestilence, but mounts above the clouds to await fresh combinations, by means which nature has appointed to render it again useful and salubrious. One great use of *lightning* may perhaps be to promote the union of this nitrogen with the *oxygen* of the water which is held in solution in atmospheric air. That the Deity has established some way of effecting this is evident, for without some such contrivance the purity of the atmosphere could not be preserved. Winds also may probably promote this union.

"His *wisdom* guides the rushing wind,
Or tips the bolt with flame:
His *goodness* breathes in every breeze,
And warms in every beam." DARWIN.

* The measure here alluded to is the common *wine* pint. From this one may deduce by calculation, that a cubic foot of atmospheric air weighs nearly one ounce and a quarter, and a foot of water 1000 ounces avoirdupois.

† It is of importance to satisfy a young person of *the truth* of every thing we teach him, and whenever it can be done it ought not to be omitted. By inverting a glass goblet over a cup of hot water, the vapour will be seen to condense upon the cold glass and run down its inside; which will show that steam is *real* water, and can become water again.

‡ Here the pupil may be informed, that water not only becomes converted into steam by heat, but, that when it is received into the atmosphere, if the air be warm, it becomes so far changed by its union with the matter of heat as to be perfectly invisible. In this state it occupies a space 1400 times greater than in its ordinary liquid state.

§ An instrument has been invented for showing the relative moisture of the atmosphere, called an *hygrometer*. This instrument shows when aqueous vapour dissolves with difficulty in the atmosphere, or when vapours are about to precipitate upon the earth—but it will not indicate the real quantity of water in any given portion of atmospheric air. There is a great variety of th[illegible]ments, all made with porous substances, which contract and dilate

Is this effected in any of the great operations of nature?

Yes: a great part of the rain which falls upon the earth becomes changed at length into vapour*, and rises into the air in that state to form clouds.

What is the cause of the waters of the earth being thus vapourized?

As the rays of the sun warm the ground†, a portion of the matter of heat combines with a portion of the water of the earth, and converts it into vapour‡.

But what causes the vapour to rise in the air?

If a cork be placed at the bottom of a bason of water, it rises immediately to the top, because it is specifically lighter than the

according to the dryness or moisture of the air. Slips of whale bone, strings of cat-gut, and the beard of the wild oat, are the substances most commonly employed in fabricating these instruments.

* Bp. Watson found that, even when there had been no rain for a considerable time, and the earth was dried by the parching heat of summer, it still gave out a considerable quantity of water. By inverting a large drinking glass on a close mown grass-plat, and collecting the vapour which attached itself to the inside of the glass, he found that an acre of ground dispersed into the air above 1600 gallons of water in the space of 12 hours of a summer's day. —Watson's Chymical Essays, vol. iii.

The ocean loses many millions of gallons of water hourly by evaporation. The Mediterranean alone is said to lose more by evaporation than it receives from the Nile, the Tiber, the Rhone, the Po, and all the other rivers that fall into it. This water is conveyed by the winds to every part of the continents; —these it fertilizes in the form of rain, and afterwards supplies the rivers, which flow again into the sea. This is one of those continual circulations whereby *all* matter is made to subserve *various* purposes, which have been devised by the Creator for the promotion of his beneficent designs.

"The bounteous sun
Lifts the light clouds sublime, and spreads them thin,
Fleecy and white, o'er all surrounding heaven." THOMSON.

In our climate evaporation is found to be about four times as much from the vernal to the autumnal equinox, as from the autumnal to the vernal. Heat facilitates all solutions; and the greater the difference between the temperature of the air and the evaporating surface, the greater will be the evaporation.—Walker's Lectures, vol. i. 237.

† In winter the earth, at eighteen inches depth, is warmer than the air; in summer, the air is warmer than the earth at that depth: these effects are owing to the earth being a bad conductor of heat.

‡ The action of the sun upon the earth in producing vapours, &c. is easily explained on chymical principles. Nicholson, or any of the other modern writers on natural philosophy, may be consulted. The shelter which is afforded to the earth by clouds, mists, &c. is due to the operation of this cause.

To this all powerful principle we owe
The copious mists which shield this world below;
Which give it how to bear the solar rays,
And roll unscorch'd beneath the torrid blaze.

water*; so vapour rises in the air, because it is specifically *lighter* than the air†.

What becomes of the water which thus evaporates from the earth?

It occupies the lower regions of the atmosphere‡, and is preserved there partly dissolved§ in air‖, and partly in the state of elastic vapour.

* I have introduced this and other very familiar examples, because I think it of consequence that those who have the care of very young people should encourage them to inquire the *cause* of every thing which they see around them. A preceptor, who is well qualified for his employment, will not think any thing too trivial which can furnish him with an opportunity of imparting useful knowledge.

† It is evident that water exists in the atmosphere in abundance in the driest seasons and under the clearest sky. There are substances which have the power of absorbing water from the air *at all times*; such as the fixed alkalies, and sulphuric acid; the latter of which will soon absorb more than its own weight of water from the air when exposed to it.

‡ There can be no doubt but that *in general* the vapours occupy the lower strata of the atmosphere: that they sometimes ascend very high, is also true; for it is well known that clouds are seen *forming* above the tops of the highest mountains. Indeed, the clouds *begin* to form always at some considerable height. Dr. Thomson, vol. iii. 373.

"At first a dusky wreath they seem to rise
Scarce staining ether; but by swift degrees,
In heaps on heaps, the doubling vapour sails
Along the clouded sky."

THOMSON.

§ Persons who have been in the habit of making observations on the clouds may have sometimes noticed a cloud, which appeared to be just in the act of precipitating, suddenly arrested by a warm current of air, and entirely dissolved thereby, so as to become in a few seconds invisible. This is the same kind of solution as takes place whenever a warm breeze passes over a river, or the ocean. Whenever the air is ponderous, and susceptible of holding the aqueous vapour in solution, the mercury in the barometer rises up to 30 or upwards; when lighter, and liable to suffer the vapours to coalesce, its pressure is less on the base of the barometer, and the mercury falls. See a further account of the barometer in the next chapter.

‖ By the experiments of Saussure it appears that a cubic foot of atmospheric air will hold eleven grains of water in solution. From this property of the air we derive many advantages. It has a tendency to preserve every thing on the face of the earth in a proper degree of moisture. In one season of the year, in the interior parts of Africa, a wind prevails called the *Harmattan*, which is so extremely dry that household furniture is destroyed by it; the pannels of wainscots split; boarded floors are laid open; and the scarf skin of the body peels off, during its continuance. Were it not for the property which atmospheric air has of holding water in solution, this would be the case every where.

It appears from the experiments of some aëronauts, that the air is much drier in the higher regions than it is near the surface of the earth. Phil. Mag. vol. xix. 378.

How is this vapour formed into clouds?

After it has remained some time in the atmosphere, it becomes in a measure condensed by causes unknown to us*; and the particles of water of which it is composed unite, and form small hollow vesicles, which accumulate together† and produce clouds.

What further changes take place in this aqueous vapour?

By the operation of causes which are also in a great measure unknown, the clouds after a time become further condensed, and are converted into water‡.

What is the consequence of this change of vapour into water?

When the vapour is condensed, it becomes too heavy for the air to support, and falls down in rain§, hail, or snow.

* The formation of clouds was formerly attributed to the solution of water in atmospheric air, and the production of rain to the mixture of airs of different temperatures; but there are so many difficulties attending every hypothesis, that I believe chymists in general now consider these operations of nature inexplicable. The subject is well investigated by Dr. Thomson, in vol. iii. of his System of Chymistry; and he concludes from all the facts, that the formation of clouds and rain cannot be accounted for by a single principle with which we are acquainted.

† Saussure conjectures that it is the electrical fluid which surrounds these vesicles, and prevents them from dissolving in the air. These vesicles are said to be from 1-380 to 1-190th of a line in diameter.

An elaborate essay, by Luke Howard, Esq. on the various forms which clouds assume, may be seen in the 16th and 17th volumes of the Philosophical Magazine.

See Dr. Darwin's account of his theory of rain and dew, in Notes to the Botanic Garden, part i. pages 114 and 169.

‡ It has before been remarked, that a portion of the water which rises in vapour is held *in solution* by the atmospheric air. When two opposite currents of air meet, of different temperatures, the vapours are sometimes condensed thereby, and rain follows. All the known gases have also the property of taking up water and holding it in solution.

It may be remarked, that if the temperature of our atmosphere had been 212°, or upwards, rain could never have fallen upon the earth; for the water taken up by evaporation would have been converted into a *permanently* elastic fluid. It is impossible ever to contemplate the various ways in which the different operations of nature are made to correct and balance each other, without being struck with the infinite comprehension of the Divine mind, which could thus foresee the tendency of every law which it was about to establish. How *many* cases are there in which the slightest oversight would have produced the destruction of a world!

§ It may be observed that rain not only affords a proper degree of moisture to the vegetable creation, but is of service in bringing the soils into a proper state to perform their office. *Dry* earth of itself has little effect; but when *moistened* it has the property of decomposing atmospheric air, and of conveying its oxygen to the roots of those plants which vegetate within it. We are indebted to Humboldt for the knowledge of this fact.

"The clouds consign their treasures to the fields,
"And, softly shaking on the dimpled pool
"Prelusive drops, let all the moisture flow
"In large effusion o'er the freshen'd world." THOMSON.

What is the use of this constitution of nature?

This principle of evaporation is of very general utility*: it is subservient to many natural processes, and is perpetually of use to man in every occupation of life†.

What is the ultimate use of this principle?

The Almighty has contrived that moisture should continually rise from the earth, and from the various bodies upon its surface, to *shield* this world of ours from the intense heat of the sun, and to return in rain to water the ground, causing grass to grow for the cattle, and corn and herbs for the service of man‡.

* This principle of evaporation not only is the primary cause of all rain, mist, dew, &c. but it moderates the effects of the sun's heat, by carrying off an immense quantity of caloric in combination with the aqueous vapours. Were it not for the cold produced by evaporation, we should faint under any great bodily exertion, or die by excessive heat.

But Nature always provident, has furnished man with a fluid, the product of an animal secretion, which, insensibly perspiring and becoming evaporated from the surface of the body, is the vehicle which carries off the superabundant heat as fast as it is generated. Cold blooded animals, whose temperature is regulated by the medium in which they live, never perspire; but man, who is intended to live in a variety of climates, and designed for active exertion, is thus preserved from the effects of heat, which would otherwise be destructive. The blood of an inhabitant of the torrid zone is no warmer than that of an inhabitant of the mountains of Lapland; which may be proved by placing a thermometer upon the tongue or under the arm. How various are the means which have been adopted for the promotion of our convenience and comfort!

The operation of this principle may be made apparent by the following experiment: Take a small tube with a little water in it, fold a little lint close round it, and, having immersed it in ether till the lint is soaked through, hold it in the air for the ether to evaporate. The cold produced by this evaporation will cause the water in the tube to freeze. If the outside of the glass tube be scratched with a flint or a diamond previous to its being wet by the ether, the effect will more readily take place.

† A little reflection will convince any one of the importance of the principle of evaporation. Innumerable instances of its use might be adduced: suffice it to say, that without it neither grass nor corn could be sufficiently dried to lay up for use. Our clothes when washed could not be dried; neither could a variety of the most common operations be carried on, which conduce much to our comfort and convenience.

‡ It is a characteristic of the works of creation that they will bear examination, and that the more they are examined the more pleasure they afford. The *simplicity* of the means which NATURE has chosen for performing the necessary operation of watering the earth, must strike every one who has any relish for what is grand and excellent. And surely the consideration of such subjects is not without its use; for, "who can meditate on the *order* observable in NATURE, and not endeavour to reduce his conduct to a similar sta[illegible]egularity?"

CHAPTER II.

OF ATMOSPHERIC AIR.

WHAT are the obvious properties of atmospheric air?*

Fluidity†, elasticity‡, expansibility, and gravity.

What do you mean by the elasticity of the air?

If atmospheric air be compressed into a small compass, it has the property of recovering its former state, as soon as the pressure is removed; which is called its elasticity§.

* The habitable and cultivated parts of the earth are lavishly adorned with every thing to gratify the eye; its diversified appearance communicates pleasure, and prevents satiety; while the whole is surrounded by an atmosphere which preserves vegetable and animal life. It may be remarked, that to the *transparency* of this atmosphere we owe all the pleasure we receive from the variegated prospects which the earth affords.

† The fluidity of the air was considered in the last chapter. See page 33.

‡ If a bladder be tied up with a very small quantity of air within it, and put under the receiver of an air pump, it will be seen to inflate gradually as the pump is exhausted, till it becomes of its full size, owing to the *elasticity* of the small quantity of air within the bladder, which dilates in this manner, as the atmospheric pressure is removed. A wrinkled apple placed under the receiver of an air pump becomes plump and smooth, from the same cause. The elasticity of the air is such, that Mr. Boyle caused it to dilate by means of an air pump till it occupied nearly fourteen thousand times the space that it usually does.

The elasticity of the air is proved by carrying a bladder half full of air to the top of a high mountain; for the air will be perceived to expand gradually as it approaches the summit, till the bladder is swollen to its usual size.

Atmospheric air may be compressed into about the 128th of its usual volume; but if an apparatus could be procured of sufficient strength, it might doubtless be compressed to a much greater degree. Owing to its elasticity, it recovers its usual bulk as soon as the pressure is removed. Saussure made use of an instrument to show the elasticity of the air, which he called a *manometer*. It was a barometer inclosed in a well luted globe. Being thus inclosed, it was only sensible to the elasticity of the air within the globe. Berthollet's Chymical Statics.

§ It is now generally supposed that the air owes its elasticity to the *caloric* which it contains; and that, if it could be deprived *entirely* of its caloric, it would lose its elastic form.

What is meant by the expansibility of the air?

The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space than it otherwise would*.

How far does the atmosphere extend?

The atmosphere is several miles high, but how far it extends is not exactly known†.

The rebounding of a common foot-ball would be a familiar instance to explain the elasticity of the air to a child.

Bubbles of air rising from the bottom of a glass of water will be seen to *dilate* as they rise to the surface; owing to the pressure of the liquor becoming less and less.

The air gun and the forcing pump are constructed on this principle. It is owing to this property of the air that fishes are enabled to rise and sink in the water; nature having furnished them with an *air-bladder*, which they have the power of contracting or dilating at pleasure. When the animal compresses this bladder, its whole volume becomes less, and it sinks in the water: when the pressure is removed, the air within the bladder instantly expands, and the creature is enabled to rise.

Mr. Gregory has remarked that, if the air were not elastic, and so fluid as to be easily put in motion, there would be an end to all the melody and harmony which now so much delight us. How admirably is every thing contrived, that it may not only administer to our wants, but be subservient to our pleasures also! That *music* was designed by the Deity to produce particular effects on man, might be shown very satisfactorily; but there is not room in this place for such a discussion. Though one may say with Mr. Hayley,

> "That Heaven is pleased, when this bright power
> "Dispels the clouds of earth, too apt to lower
> "On every human mind, in life's precarious hour."
>
> HAYLEY'S Triumphs of Music.

* If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

Mr. Robins has calculated, that the air which is disengaged in the firing of gunpowder is rarefied by the heat, so as to occupy a thousand times the space of the whole of the gunpowder employed.

"The dilatation or expansibility which bodies experience by a given elevation of temperature, is much more considerable in elastic fluids than in liquids." Atmospheric air is an instance of the truth of this chymical axiom. Whenever this expansibility takes place, caloric is absorbed.

† If the atmosphere were of the same density throughout, its height might be known by its effect in raising a column of water or mercury; but as it increases in rarity the higher it ascends, and is probably extremely rare in the higher regions, we cannot possibly tell how far it may extend. It was attempted to calculate the extension of the atmosphere by ascertaining its *comparative* rarity at different heights; but this also was found to be impracticable. Since then, it has been estimated by the length of our *twilight*, and supposed to be about forty-five miles high. If we had no atmosphere, we should be in total darkness at the *instant* the sun sinks below the horizon; but as the sun illuminates the atmosphere for some time before it rises, and after it has set, the light is reflected by the atmosphere to the

the feathered creation to transport themselves with ease from one part of the earth to another*.

But what is the use of the atmosphere being extended so far above the surface of the earth?

It is this extension of the atmosphere which occasions its *weight*; and this great weight produces many important effects in the economy of nature†.

mospheric air, *man* is the only being who gives to it all the modulations of which it is susceptible. With his voice alone, he imitates the hissing, the cries, and the melody of all animals; while he enjoys the gift of speech denied to every other. To the air he also sometimes communicates sensibility; he makes it sigh in the pipe, lament in the flute, threaten in the trumpet, and animate to the tone of his passions, even the solid brass, the box tree, and the reed. Sometimes he makes it his slave: he forces it to grind, to bruise, and to move for his advantage an endless variety of machines. In a word, he harnesses it to his car, and obliges it to waft him over the stormy billows of the ocean."

* Messrs. Robertson and Saccharoff, who ascended with an air balloon from Petersburgh, in June 1804, took some live pigeons with them. At different heights they gave liberty to their birds, who seemed not very willing to accept it. The poor animals were so terrified with their situation, that they clung to the boat till forced from it; when it appears their fears were not groundless; for, on account of the *rarity of the air*, their wings were nearly useless, and they fell towards the earth with great rapidity: the second struggled with eagerness to regain the balloon in vain; and the third, thrown out at the greatest elevation, fell towards the earth like a stone, so that they supposed he did not reach the earth alive. Retrospect, vol. i. 94.

This relation affords a fresh instance of the harmonies of Nature, and of the suitableness of every creature to the medium in which it was designed to live. The density of the air, *near* the surface of the earth, we see is *exactly* what was requisite for the residence of the feathered race; and the specific gravity of every individual, of every species, is just sufficient to enable it to occupy that element, and to move within it at all times with ease and safety. The most acute fatalist would surely be puzzled to account for these congruities. Let us attribute them to the contrivance of that Being, who never bestows existence but for the sake of conferring felicity, and we are at once in possession of the most satisfactory solution.

† The *pressure* of the atmosphere may be shown by a simple experiment. Place a card on a wine-glass *filled* with water; then invert the glass, and the water will not escape; the pressure of the atmosphere on the outside of the card being sufficient to support the water.

The same thing may be shown by a different experiment. Invert a tall glass jar in a dish of water, and place a lighted taper under it. As the taper consumes the air in the jar, its pressure becomes less on the water immediately under the jar; while, the pressure of the atmosphere on the water *without* the circle of the jar remaining the same, part of the water in the dish will be forced up *into* the jar, to supply the place of the air which the taper has consumed. Nothing but the pressure we are speaking of, could thus cause a part of the water to rise within the jar, above its own level.

Again, the reality of the atmospheric pressure may be explained and demonstrated by a common barometer, merely by showing how it acts upon that instrument.

What are the effects of the weight of the atmosphere?

It is owing to the *weight* of the atmosphere that we are enabled to raise water by the common pump*, and to perform many other useful operations.

What other advantages do we derive from this extension of the atmosphere?

If we had little or no atmosphere, we should have no cold water; for the waters on the face of the earth would all boil at a very inferior temperature†.

"In tubes of glass mercurial columns rise,
"Or sink, obedient to the incumbent skies."

It is this action of the atmosphere which enables the limpet to attach itself to the rocks. It forms a vacuum in its pyramidal shell, and the pressure of the atmosphere supports it where it wishes to remain, without any further exertion of its own.

* It is impossible for a child to understand this, unless it be particularly explained to him; which may be done by telling him, that the atmosphere presses *equally* upon the whole surface of the water in the well, until the rod of the pump is moved; but that by forcing the rod down, the bucket compresses the air in the lower part of the pump tree, which being elastic, forces its way out of the tree through the valve; so that when the bucket is again raised, that part of the pump tree under the bucket is void of air; and the *weight of the atmosphere* pressing upon the body of water in the well, forces up a column of water to supply its place; that the next stroke of the pump rod causes another column of water to rise, and that as long as the bucket fits the pump tree close enough to produce a vacuum, a constant stream of water may be drawn from below. By cutting a piece of writing paper in the form of a valve, and adapting it to the top of an ale-glass, it will be no difficult thing to explain how the successive columns of water force up the valve in that tree, and how that valve supports the water when raised, and prevents its return. See Additional Notes, No. 12.

"Press'd by the incumbent air, the floods below,
"Through opening valves, in foaming torrents flow,
"Foot after foot in lessen'd impulse move,
"And rising seek the vacancy above." DARWIN.

A common syringe (which may be bought for a few pence) will show the action of the atmospheric air in pumping.

When a child sucks at the breast, it forms a vacuum with its mouth, and the milk flows on the same principle. See Additional Notes, No. 2.

In like manner the boy forms a vacuum between a piece of wet leather, tied to a string, and a pebble stone; and, by means of the pressure of the atmosphere, is enabled to lift the pebble from the earth and carry it about, suspended by the leather. The common syphon is indebted to this pressure also for its action.

It may be remarked, that these effects are attributed by the vulgar to what they call suction; but it has frequently been demonstrated, that no such principle as suction exists. The pressure of the atmosphere is fully sufficient to account for them all.

† On the tops of very high mountains, water will boil much sooner than it will on the plains, (where the atmosphere is heavier); and it is known

Besides, the arterial vessels of all organized beings would be so constantly distended, that animal and vegetable life would be endangered.

How are waters and other fluids preserved to us by the weight of the atmosphere?

The weight of the atmosphere, pressing on the water, binds it down as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour*.

that many spiritous liquors, such as ether and spirits of wine, lose a great part of their qualities when exposed at such heights. See some interesting experiments in the first chapter of Lavoisier's Elements, also Additional Notes at the end of this volume. No. 3.

The quick evaporation which would take place if we had no atmosphere, may be shown by a common instrument, invented by Dr. Franklin, called a pulse-glass. It is a small tube with a bulb at each end, exhausted of its air, and containing a small quantity of spirits of wine. If this instrument be held sloping, with one end in the palm of the hand, the *heat* of the hand will quickly cause the spirit to boil; but the vapour rising to the other end, becomes condensed as soon as it comes in contact with the cold glass. This a very cheap and simple experiment, and shows that a very *small* degree of heat would be sufficient to evaporate most of our fluids if we had no atmosphere. This instrument is also calculated to show that evaporation produces cold; for the instant that the spirit begins to boil, a sensation of sudden cold is felt on that part of the hand where the bulb rests.

It is the principle of evaporation producing cold which occasions the injury which persons sustain by sitting in wet clothes. In these circumstances, it is not the water which hangs *upon* them, which produces the mischief, but the sudden loss of a large portion of caloric, which is carried off from the body by the *evaporation* of this water. If a healthy person were *closely* covered up with his wet clothes, so that no evaporation could take place, he would probably sustain no injury.

* That the waters on the face of the earth would be dissipated in vapour by a small degree of heat, if we had no atmosphere, may be shown by the following simple experiment:—Procure a bottle with a very long neck, *fill* it with boiling water, and cork it close so as to exclude the air. Then if it be put to stand in a bason of cold water, the water will sink in the neck of the bottle as it cools. This shrinking of the hot water will produce a vacuum in the upper part of the bottle, when the water within it will be seen to recommence its boiling with great violence. This can be owing to nothing but the cork taking off the pressure of the atmosphere from the water. In like manner, water which has been cooled many degrees below boiling will begin to boil again if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air. Under the pressure of the atmosphere water boils at 212°, but *in vacuo* it boils when heated only to 67°. On the contrary, if additional pressure be given to water by a Papin's digester, it may be heated to 400°, without ebullition. Lead has often been melted by the water heated in these digesters.

Some philosophers have asserted that, if the atmospheric pressure were entirely removed, all substances on the face of the earth, solid as well as fluid would be dissipated in vapour.

If a small thin glass jar be half filled with good ether, and placed within another jar half filled with water, and both be put under the receiver of an

How does the weight of the atmosphere operate, so as to be beneficial to the animal and vegetable creation?

The uniform pressure of the atmosphere on the *exterior* of all organized beings counterpoises the *internal* pressure of the circulating fluids, and preserves the vessels in due tone and vigour*.

What is the weight of the atmosphere?

It is about 2160 pounds upon every square foot. A column of air an inch square weighs about 15 pounds†.

air pump, when the air is exhausted the ether will boil, and the water be frozen. (Walker.) The cause of these effects may be thus explained:— When the pressure of the atmosphere is removed by the air pump from the surface of the ether, its own latent caloric occasions its expansion, and, absorbing caloric from the water, it becomes converted into gas; and the water, having lost its caloric of fluidity, becomes ice.

The best elucidation of the nature of the pressure of the atmosphere, which I have seen, is in "Brisson's Physical Principles of Chymistry," section 31, and the following. See also Additional Notes, No. 4.

* Were it not for the pressure of the atmosphere constringing the vessels in men and vegetables, the elastic fluids contained in the *finer* vessels would inevitably burst them, and life become extinct. Count Zambeccari and his companions, who ascended with a balloon to a great height on the 7th of November 1783, found their hands and feet so swelled, that it was necessary for surgeons to make incisions in the skin. They ascended to so great a height, that the pressure of the atmosphere was not sufficient to counterbalance the pressure of the fluids of the body.

Persons who have delicate constitutions need not wonder that they are generally much affected by a change in the atmosphere, when they learn that often in the course of a few hours the atmospheric pressure, on *each* individual, is increased or diminished from one hundred weight to half a ton weight; while the *internal* pressure of the circulating fluids remains the same. Supposing a man's body to contain 15 square feet of surface, (which is near the truth), he will sustain a body of air upwards of fourteen tons weight. But it is necessary to remark that the air presses upwards, downwards, and sideways, in every direction; and that it is owing to this *equal* pressure that animals, &c. are not injured by the vast weight of the atmosphere; for the equal pressure, on all sides, resists as much as it is resisted.

Whenever I hold my hand out in this fluid, I feel no weight upon it because the pressure under and above my hand is equal: but if I lay my hand on a hollow cylinder of glass, placed on the plate of an air pump, and exhaust the air out of the cylinder, I become immediately conscious of something that presses my hand so forcibly to the glass, that I cannot release it. The prop is now gone; I have no pressure under my hand; a column of air, 45 miles high, presses down my hand by its weight, and I must let in the air under it, before it will be released. Walker.

"Mr. Coates computed the weight of the air which presses upon the whole surface of the earth, and found it to be equal to that of a globe of lead sixty miles in diameter." Cyclopædia.

† A column of air of the height of the atmosphere, when greatest, is equal to a column of water 35 feet high, or a column of mercury of the same size 30½ inches high. Hence water will not rise in a pump more than 35 feet, nor mercury in a barometer stand higher than 30½ inches. See Additional Notes, No. 2.

A quart measure of atmospheric air weighs about 17 grains.

What other advantages do we derive from this immense atmosphere?

The great thickness of the atmosphere gives a proper temperature to the rays of the sun: it also reflects those rays so as to give a lucid brightness to every part of the heavens*: and is the cause of those dews and rains which make the earth fruitful†.

Have you learnt any thing of the nature of the air which forms the atmosphere of this earth?

Yes: it is a mixture *chiefly* of two different airs‡, which are chymically combined§ in certain proportions‖.

What do you call these airs which compose our atmosphere¶?

* If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case there would be no substance to reflect the rays of the sun to his eyes. It is owing to this reflection that the sun enlightens the earth some time before it rises, and some time after it sets. See this explained with perspicuity by Gregory, in his Astronomical Lessons, page 78—81.

† The atmosphere is the cause of evaporation: it is the atmospheric air which holds the aqueous vapours in solution, and preserves them in a gaseous state till they are condensed again into rain.

‡ Pure atmospheric air is composed of three gaseous substances only, but it is perpetually contaminated by a variety of exhalations from the earth. "The atmosphere is a vast laboratory, in which nature operates immense analyses, solutions, precipitations, and combinations: it is a grand receiver, in which all the attenuated and volatilized productions of terrestrial bodies are received, mingled, agitated, combined, and separated. Notwithstanding this mixture, of which it seems impossible for us to ascertain the nature; the atmospheric air is sensibly the same, with regard to its intimate qualities, wherever we examine it." Fourcroy.

§ When the nature of atmospheric air began to be understood, it was imagined that it was a mere *mixture* of oxygen gas and nitrogen gas, but we have now abundant reason to believe that it is a real chymical compound; that is, that the oxygen and nitrogen form atmospheric air by a chymical union. Dr. Thompson, vol. iii. 314.

Mr. Dalton, an ingenious modern chymist, is still of the first opinion; but an experiment, made by some friends of mine on a large scale, proves, I think, the fallacy of his theory. In order to produce sulphuric acid, without the intervention of nitre, they caused a stream of atmospheric air to be thown upon burning sulphur, from a very powerful bellows constructed for the purpose; and though the experiment was made under the most favourable circumstances, and the blast kept up for three days, no portion of sulphuric acid was formed. Does not this prove that oxygen has a greater affinity for nitrogen than for sulphur, and that atmospheric air is not a mixture, but a chymical compound?

‖ According to Mr. Davy, the air of Europe, Asia, Africa, and America, differs very little in the proportion of its ingredients. Journal Roya Instit.

¶ The atmospheric air is a chymical mixture of two distinct and *solid* s[illegible] viz. oxygen and nitrogen, rendered aërial by the expansive [illegible]loric: it likewise contains a portion of carbonic acid gas.

They are called oxygen air * and nitrogen air.

Are oxygen and nitrogen the only substances which enter into the composition of the atmosphere?

No: atmospheric air contains also one part in every hundred of carbonic acid gas†, and several adventitious substances.

What other substances are found in atmospheric air?

Besides carbonic acid gas, which is chymically combined with the air‡, it holds a portion of water in solution§; and sometimes

* The respirable part of atmospheric air has been called oxygen, on account of its acidifying principle; the other part has been termed azote, from its known quality of killing all animals which are obliged to breathe it, when separated from oxygen. The terms are taken from the Greek language. I have in this work substituted *nitrogen* for azote, because it is the base of nitric acid, and it agrees in *termination* with oxygen and hydrogen. Carbonic acid gas and hydrogen gas are as incapable of supporting life as nitrogen; therefore there is no reason why one should be called azote more than the other.

It should be remarked, that oxygen requires *light* as well as caloric in order to convert it into vital air. During combustion, the vital air gives out this light in every direction.

† If a pure alkali or an alkaline earth be exposed to the atmosphere, it will gradually absorb carbonic acid. This is also the case with several of the metallic oxides. As atmospheric air is always furnished with carbonic acid, no wonder that so large a number of the salts are found in the state of carbonates.

Carbonic acid gas is found to exist in the atmosphere not only near the surface of the earth, but at the greatest heights; which is a proof that it is not a mere mixure, but that it is chymically combined with the air. Saussure found it at the top of Mont Blanc, which is esteemed the highest point of the old continent. However, it is probable that the proportion of carbonic acid is not so large at great heights as it is near the earth; for the unfortunate philosophers who attended La Perouse in his last voyage could not detect it in the atmosphere at the summit of the peak of Teneriffe.

La Perouse's Voyage.

Dr. Thomson has calculated, that on the supposition of there being 1 per cent. of carbonic acid dispersed throughout the atmosphere, its absolute quantity would amount to more than one hundred millions of hundred millions of pounds avoirdupois; and remarks "that this enormous quantity undoubtedly serves some valuable purpose in the atmosphere, though our knowledge of the changes which go on in that great laboratory is at present too imperfect to enable us even to conjecture the uses to which it may be applied."

System of Chymistry, vol. iii. 330.

Some of the uses of carbonic acid gas in atmospheric air I think are very apparent. Without it none of our buildings would acquire the necessary degree of firmness, as it is well known that mortar hardens in consequence of the absorption of this gas; and if the atmosphere was entirely divested of it, it is doubtful whether plants of all kinds would vegetate as they now do; for its base is the proper food of vegetables, and nature has given them the means of decomposing it.

‡ Carbonic acid gas is nearly twice as heavy as common air: hence it is evident that it must combine *chymically* with the atmosphere, or it would be found only near the surface of the earth. If it was merely *mixed* with the atmospheric air, its gravity would prevent it from ascending to any great height.

§ Upon an average, atmospheric air contains about 1 per cent. of water in the state of elastic vapour.

contains hydrogen gas* and carburetted hydrogen.

What are the sources of these other gases?

Carbonic acid gas is constantly formed by the respiration of animals and by combustion†; and hydrogen gas, and carburetted hydrogen gas, arise from various sources, particularly from marshes, stagnant pools, &c. all which are prejudicial to the animal creation.

If carbonic acid air and carburetted hydrogen air are prejudicial to animal life, how are they corrected in the atmosphere?

These airs, which would cause the death of any animal obliged to breathe them‡, are the proper nutriment of vegetables, and nature has endowed them with organs for their decomposition.

You have spoken of different gases; what do you mean by gas?

* It is remarkable, that whenever aqueous vapour is added to atmospheric air an augmentation of volume is the consequence, and damp air is always specifically lighter than dry air. This shows that it is not a mere mixture, but a chymical combination.

From the frequent decompositions which are taking place upon the surface of the earth, the atmosphere must always contain a portion of hydrogen gas; but we have no ready means of detecting it.

† The quantity which is daily formed by these processes is so great, that it must have increased rapidly, had the Almighty not provided means for its being as rapidly decomposed. The wisdom and goodness of this appointment must be apparent to those who know that whenever atmospheric air becomes charged with one tenth of this gas, it is unfit for promoting combustion, and is fatal to most animals that are obliged to breathe it.

‡ Every chymist must be aware that a large quantity of *carburetted hydrogen gas* is perpetually evolved at the surface of the earth; he must also know that this gas is fatal to animal life. I could adduce a melancholy instance of a gentleman who inhaled it by mistake, and died almost immediately in consequence of it. How then has the all-wise Artificer of the world contrived to protect its inhabitants from the baneful influence of that immense quantity with which the atmosphere is perpetually contaminated? the means are as simple as they are important—Vegetables are so constituted that *carbon* and *hydrogen* are the necessary food of plants, and conduce to the support of vegetable life: their vegetating organs seize the *carbonic acid gas* which comes within their reach, and while they appropriate the *carbon* to themselves, the *oxygen* is thrown off to renovate the atmosphere by its union with the nitrogen rejected by animal respiration. As all vegetables are in want both of carbon and hydrogen, there can be little doubt but that by their means the atmosphere is divested of *carburetted hydrogen gas also*. Thus, what is noxious to man is rendered beneficial to vegetables; and the oxygen which vegetables are not in want of, is separated by them in its utmost purity for the use of man. The wisdom, the simplicity, and the beneficence of this arrangement are so striking, and address us with so much effect, that the mind of the reader may be left to make its own reflections on the goodness of the Deity.

> Eternal ruler of the skies,
> How *various* are thy works, how wise!
> How great and good! what tongue can frame
> An equal honour to thy name! MERRICK.

See Additional Notes, No. 5.

When solid substances are rendered aëriform by heat, the air thus produced is called a *gas**.

Is there any chymical means of analysing the atmospheric air?

By the operation of different agents, the several gases may be separated from each other, and the quantity of each ascertained†.

Do you know the proportions of the different gases in atmospheric air?

There are about 22 parts of oxygen, 77 of nitrogen, and one of carbonic acid gas, in every 100 measures of atmospheric air‡.

* Van Helmont was the first chymist who made use of this term to denote an elastic fluid. He gave fixed air the name of *gas*.

All the simple gases are formed with a substance more or less *solid*, and caloric. It is caloric which separates the particles, and gives to the whole a gaseous form. In order to produce any of the gases, heat is generally made use of, though sometimes we have recourse to the acids for this purpose.

The gases are elastic, invisible, ponderable, and permanently aëriform, unless condensed by chymical combinations.

The permanency of the gases appears to be owing to the strength of the affinity existing between caloric and their bases, which affinity resists every reduction of temperature.

When gases are produced by distillations, or by chymical mixtures, the radical of the gas is not merely heated by caloric, but caloric is chymically *combined* with it, and forms one of its necessary component parts. Some of the gases, such as muriatic acid gas, nitrous gas, &c., may be condensed by water; but in this case a new combination is formed by the acid and the water, and the caloric is disengaged in the form of sensible heat.

For an account of the method of collecting gases, and of transferring them from one vessel to another, consult Berkenhout's First Lines of Philosophical Chymistry, page 204, where the necessary apparatus is minutely described, and appropriate drawings are annexed.

The pneumatic trough which is used for these purposes was invented by Dr. Priestley. A common tub with a shelf fixed in it was what he first used; but he was afterwards furnished with a very elegant apparatus which the amiable Duke of Rochefoucault sent him from Paris.

† The method of doing this may be seen in Lavoisier's Elements of Chymistry, or in Bouillon la Grange; to which I refer the reader.

The gases have been divided by some writers into two classes, viz. those that are *respirable* and capable of maintaining combustion, and those that are *not respirable*, and incapable of maintaining combustion. It is remarkable that if we attempt to breathe any of the non respirable gases, they stimulate the muscles of the epiglottis in such a manner, as to keep it perfectly close, and prevent (in opposition to our exertions) the smallest particle of gas from entering into the bronchia.—(Accum's Chymistry.) Some modern atheists have asserted that the members of the animal body have acquired their adaptation to the wants of the individual by habit; and that they have been gradually formed to what we see them by repeated use from generation to generation; but here is an instance of the parts *refusing action* for the preservation of the animal. This peculiar faculty therefore (as a celebrated writer has remarked in another instance) could not have grown out of the use of the parts though it had had an eternity to grow in. It can only be attributed to that beneficence of contrivance which in so many instances excites our gratitude and admiration.

‡ The proportions, according to Lavoisier and other writers, are 27 of

Is there much difference in the nature of these gases?

Yes: they are of different and opposite qualities*.

What are the properties of oxygen gas?

The oxygen gas in atmospheric air is the principle of combustion†, and the vehicle of heat‡; and is absolutely necessary

oxygen and 73 of nitrogen: and if they calculated by *weight*, these proportions will be near the truth, as the specific gravity of oxygen gas is greater than that of nitrogen gas.

The pupil may be satisfied with the truth of these proportions in various ways;—the following is the easiest:

A lighted taper will not burn in nitrogen gas a moment; if immersed in oxygen gas it burns with a splendour too great for the eye to endure: but if three measures of nitrogen gas and one of oxygen gas are put into a jar inverted over water, and a lighted taper put into such mixture, it will burn exactly the same as it does in atmospheric air.

"If a few hundredth parts of oxygen only were wanting in atmospheric air, fire would lose its strength, candles would not diffuse such complete light, and animals would with difficulty separate the necessary quantity of the vivifying oxygen. On the other hand, if the atmosphere were more charged with oxygen than nitrogen, animals indeed would acquire a freer respiration; but let us consider the activity which fire would acquire by air of superior purity. We know that, on some occasions, the least spark excites the strongest flame in a combustible body, and which increases so much as to consume it in a few moments: candles *then* would be no sooner lighted than they would be destroyed, without answering any other purpose than that of dazzling us for a few moments: iron would be calcined, instead of acquiring from the fire that softness necessary for transforming it into various instruments, and which it cannot receive in a more moderate heat. Nothing would be capable of checking the progress of this destructive element, which is nourished by vital air, if this aëriform substance were not abundantly mixed with mephitic air, which serves to restrain it." Anthony de Marti on the Constitution of the Atmosphere.

* These gases are of such opposite qualities, that the one is sometimes called *vital* air; while the other, from its causing the death of those who breathe it, is by the French chymists (as has before been remarked) called azotic gas.

† The necessity of oxygen for supporting combustion may be shown by the following simple experiment. Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.

‡ "Dr. Higgins having caused a young man to breathe pure oxygen gas for several minutes, his pulse, which was at 64, soon rose to 120 beats in a minute. The advantage which may be derived to the sick, by increasing or diminishing at pleasure this natural stimulus in the blood, may be easily conceived; for, by *abstracting* a part of the oxygen from atmospheric air, the pulse may likewise be lowered at pleasure." Dr. Thornton's Medical Extracts. See Additional Notes, No. 6.

Pure oxygen gas has been used also with success in cases of suspended anin

for the support of animal life*.

What is the nature of oxygen gas, when in a separate state?

Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the most rapid combustion of all combustible substances; so that it is the most energetic and powerful agent that we are acquainted with†.

What is the specific gravity of oxygen gas?

Oxygen gas is a little heavier than atmospheric air‡, and 740 times lighter than water.

What are the principal properties of nitrogen gas?

Nitrogen gas § is somewhat *lighter* than atmospheric air; very fatal to all animals; and incapable of supporting combustion.

Water impregnated with oxygen gas has been found a valuable remedy in several diseases. By depriving common water of the atmospheric air by boiling, and then forcing oxygen gas into it, I have occasioned a large absorption of it, and have found that it retained it better than carbonic acid gas is retained by water.

* It has been proved by Mr. Hassenfratz, that oxygen is necessary to promote the vigour of plants as well as that of animals; and that to this end, a much larger quantity of oxygen is combined with snow, and in rain water, than in river or spring water. See Phil. Mag. vol. iii. 239.

> LEAVES, LUNGS, and GILLS, the vital ether breathe
> On earth's green surface, or the waves beneath.

A collection of experiments on the effects of oxygen on animal and vegetable life may be seen in "Archer's Observations on Oxygen," 8vo. Dilly, 1798.

† If I were writing for adults, I should think it necessary in this place to explain the other properties of oxygen, viz. its power of oxidizing metals, and converting several substances in the mineral and vegetable kingdoms to acids: but as it will be some time before the pupil will enter upon the investigation of these subjects, I thought it most advisable not to burthen his memory with these facts at present.

‡ At the temperature of 54.50, when the barometer stands at 28 inches, oxygen gas is 12 drachms (or 1½ ounce) to each cubical foot; whereas nitrogen gas is only 10 drachms 48 grains to the cubical foot.

Oxygen gas is plentifully procured from nitre, or from the black oxide of manganese. Four ounces of nitre melted with a little slacked lime produced Mr. Ingenhouz 3000 cubic inches of vital air. See Additional Notes, No. 7.

§ Nitrogen enters into all animal substances. It is generally combined with carbon and hydrogen. It is also the base of ammonia, and of the nitric acid. It appears to be favourable to plants, as they grow and vegetate freely in this gas. It seems to be the substance which nature employs in converting vegetables to animal substances; and to be the grand agent in animalization. See Fourcroy's Philosophy of Chymistry, chap. xi.

When nitrogen gas is required for experiments, it may be procured thus, with little trouble and expence:—Take a few iron filings, mix them with a little sulphur, and moisten the mass with water. Put this mixture into a large glass jar, and cork it close. In a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residuum will be found to be nitrogen gas.

Since that nitrogen gas is so injurious to animal life, what is the use of so large a quantity of it in atmospheric air?

Nitrogen gas has the effect of neutralizing, in some measure, the properties of [illegible] gas, and rendering it fit for respiration and combustion*.

How is this change effected by nitrogen gas?

By the union of nitrogen gas with oxygen gas: the latter, which would burn every thing within its reach with an unparalleled activity, is, as it were, dissolved and diluted; and the nature of the former is so much enveloped by the latter, that the compound possesses properties, different to either of these gases, so as to be fitted for every purpose for which it was designed†.

How does the atmospheric air support life‡?

* According to Trousset, the gas emitted by the skin is pure nitrogen. Annales de Chimie, 45. 73.

† "If the proportions of oxygen and nitrogen were reversed in atmospheric air, the air taken in by respiration would be more stimulant, the circulation would become accelerated, all the secretions would be increased, the tone of the vessels, thus stimulated to increased action, would be destroyed by over-excitement; and if the supply from the stomach were not equal to the consumption, the body must inevitably waste and decay." Dr. Lambe on Constitutional Diseases.

Hence the wisdom of the Deity, in the constitution of atmospheric air, is as evident as in the nutritious quality of the food which he has provided for the support of the creatures of his formation.

† Though nitrogen gas is, by itself, so noxious to animals, it answers an important end when mixed with oxygen gas in atmospheric air. Were it not for the large quantity of nitrogen in atmospheric air, the blood would flow with too great rapidity through the vessels, and all animals would have too great spirits; the consequence of which would be, that the life of man would not be protracted to the length that it now is.

> "From Nature's chain, whatever link you strike,
> "Tenth, or tenthousandth, *breaks the chain alike.*"
>
> POPE.

Nitrogen gas has been medicinally administered with success in cases of increased irritability, such as inflammations, &c.

‡ The necessity of atmospheric air, for the support of life, was exemplified by a melancholy accident which happened to two men in the bay of Dublin, who went to visit a wreck in a diving bell. Two barrels of fresh air were to be alternately sent down to them, and the contaminated air was to be let out by a stop cock at the top of the bell. But, by the contraction which ropes suffer in being wet, the bell turned round in its descent, and entangled the strings by which the divers meant to ring bells, and indicate their wants to the peop[illegible] the ship from whence they were lowered. Waiting too long fo[illegible]ls, the bell was raised, and the divers were both found dead. [illegible] drowned, but died, like the unhappy people in the [illegible] hole a[illegible]nt of a supply of pure air. Walker, vol. i. 332.

By giving out its oxygen and caloric to the blood*.

What do you mean by caloric?

Caloric is the name which modern chymists have given to fire, or the matter of heat; a large portion of which is intimately combined with atmospheric air†.

Is the caloric which is combined with the air we breathe, sufficient of itself to keep up the necessary heat of the body?

Animal heat is preserved *entirely* by the inspiration of atmospheric air. The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body‡.

* Dr. Priestley has shown, by a variety of experiments, that the blood perpetually receives oxygen gas (or what he calls dephlogisticated air) from the atmosphere, by the agency of the lungs. See his Experiments on Air.

"The blood is *purple* when it arrives at the lungs; but having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries; the source of animal heat; and the cause of sensibility, irritability, and motion." Dr. Thornton.

Black venal blood, exposed to the air, becomes red on its surface; and air, remaining confined over venal blood, loses its oxygen, so that what remains is found to be unfit for combustion. These facts prove that the vermilion colour of the blood is owing to the inhalation of oxygen gas.

"The internal surface of the lungs (or air vessels) in man, is said to be equal to the external surface of the whole body: it is on this *extended* surface that the blood is exposed, through the medium of a thin pellicle, to the influence of the respired air." Dr. Darwin. See Additional Notes, No. 8.

"'Tis surely GOD
Whose unremitting energy pervades,
Adjusts, sustains, and *agitates* the whole.
HE ceaseless works alone; and yet alone
Seems not to work: with such perfection framed
Is this complex stupendous scheme of things."

THOMSON.

By the rise of the breast-bone in man, and the descent of the diaphragm, room is afforded for 42 cubic inches of atmospheric air at every drawing in of the breath. A deeper inspiration will give room for more than twice this quantity. Keill's Anatomy.

† This name was given by the framers of the new nomenclature to the matter of heat, which they always distinguish from the effect. Caloric is applied to fire, or the substance which produces the sensation we call heat, but never to the sensation itself, or the effect produced by fire. In this case, it is said that caloric raises the temperature of bodies, or, on the contrary, that the temperature is lowered by the loss of caloric.

‡ Dr. Menzies ascertained, that the blood in its passage through the lungs gains more than one degree of Fahrenheit's thermometer. Dr. Menzies on Respiration.

Dr. Crawford instituted a series of experiments, with a view to discover the cause of animal heat. In the course of his inquiry, he found that blood

How do clothes conduce to preserve the heat of the body?*

When the temperature of the atmosphere is colder than our blood, clothes are necessary to prevent the sudden escape of that heat from the surface of the body† which the lungs have separated from the atmosphere‡.

contains a much great quantity of absolute heat than the elementary substances of which it is composed.

According to Lavoisier, a man generally consumes 32 ounces troy of oxygen gas in 24 hours; that is, the lungs separate this quantity of oxygen gas from the air which he respires in that time.

The blood, in passing through the lungs to take up oxygen gas, throws off charcoal; for there is a larger portion of carbonic acid gas thrown out in every respiration than could be furnished by the atmospheric air.

Lavoisier has shown that, in respiration, there is a constant combination of the oxygen of the atmosphere with the hydrogen and carbon of the blood. See Additional Notes, No. 9.

> "Thus LIFE discordant elements arrests,
> Rejects the *noxious*, and the *pure* digests;
> Combines with heat the fluctuating mass,
> And gives awhile solidity to gas." DARWIN.

See a good Memoir on Respiration, and the Production of animal Heat, by Armand Seguin, in the 6th volume of the Monthly Magazine, page 94: but this subject is treated more at large by Dr. Bostock, of Liverpool, than any other writer; to whose work I would refer the reader.

* Clothes keep the body warm in consequence of the air which they infold within them; atmospheric air being a non-conductor of heat. It is on this principle that double windows preserve the warmth of apartments at an equable temperature. In like manner double lids for boilers, formed so as to hold a sheet of air, are found to be very effectual for preserving the heat of the liquor with a very small portion of fuel

† We clothe ourselves with wool because it is a bad conductor of heat, and retards its escape from the body. The inhabitants of Russia clothe themselves in fur, because fur is still a worse conductor of heat than wool. Sheep are natives of a temperate climate; but bears and ermine of the coldest. The provident care of the Creator is evidently conspicuous in this appointment, and discovers the same undeviating attention to the comfort of all his creatures: hence the clothing of animals in the torrid zone is hair, in the temperate zones wool, in the frigid thick fur.

‡ Those animals which do not breathe, such as fishes and insects, have a bodily temperature but little superior to the medium in which they live. The temperature of all animals is proportional to the quantity of air which they breathe in a given time. Man, quadrupeds, and whales, have a heart, and breathe through lungs; in consequence of which structure heat is evolved during the circulation of blood. They are therefore called warm-blooded animals. In the severest winter, or in the coldest regions that man or any quadruped can inhabit, the temperature of the body is hardly a degree lower than in the warmest summer, or in the torrid zone. A thermometer with its bulb under the tongue, or buried in a wound in any fleshy part of the bo[illegible]ys indicates a heat of 97° or 98°, be the temperature of the air [illegible]—(Skrimshire's Essays.) This astonishing effect is produced [illegible]position of atmospheric air, as explained in the preceding notes.

What becomes of the nitrogen which was combined with oxygen in atmospheric air?

The greatest part of the nitrogen is thrown out of the lungs at every respiration*; and being somewhat lighter than atmospheric air, it rises into the atmosphere to await fresh combinations†.

A postulatum has been assumed by some atheists, that the organs of the body have been formed by what they call *appetency*, i. e. endeavour perpetuated, and imperceptibly working its effects through a long series of generations: but I would ask any man of common understanding, whether he would like to assert that he believes this to have been the way in which the lungs acquired the faculty of decomposing atmospheric air; and that he believes that this hypothesis is sufficient to account for the composition of this air, which so exactly suits the operation of these lungs, and which contains that exact portion of caloric which the animal œconomy requires! It is worthy of remark, that cold-blooded animals, which are not furnished with this breathing apparatus, are so constituted that their temperature changes with every change of the temperature of the surrounding medium. "Frogs have been absolutely frozen so as to chip like ice, and yet when carefully and gradually thawed have been completely reanimated." Skrimshire.

* It is not simple nitrogen which is thrown out, but *nitrogen gas*; for, when the atmospheric air is decomposed by the lungs, only a part of its caloric is taken up by the blood, the other part remains combined with the nitrogen, to preserve it in the form of gas, and to facilitate its being thrown off by respiration.

According to Mr. Davy, a *small* portion of nitrogen (viz. 4 or 5 ounces in 24 hours) is absorbed by the blood, and furnishes the animal with one of its constituent parts. See Davy's Researches.

It may be remarked, that the interval which there is between every inspiration seems to have been designed by nature, to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed. That this actually entered into the plan of the Divine mind, may be presumed also from the levity which has been given to nitrogen gas, and which enables it to rise upwards in atmospheric air.

† It may be observed that, if the author of nature had *reversed* the specific gravity of the two constituent parts of atmospheric air, the nitrogen thrown off by the respiration of men and animals would have perpetually occupied the lower regions of the atmosphere, and produced universal pestilence. Nitrogen gas is very little lighter than atmospheric air, but probably to that *little* the atmosphere owes the salubrity it possesses. How provident has the Almighty been, in thus foreseeing the operation of those laws which were designed to promote the welfare of every species of animated beings!

"A vessel of 1000 cubic inches will contain 315 troy grains of common air; but it will contain 335 of oxygenous gas, and only 297 of nitrogen gas." Dr. Black's Lectures, vol. ii. 109.

From the experiments of some aëronauts, it appears that the air in the upper regions is more impure than that nearer the earth; which is probably owing to the greater levity of nitrogen gas, or to the effects of vegetation on the lower parts of the atmosphere. Whatever may be the cause, we cannot but admire the wisdom of the arrangement.

What provision has nature made for restoring the vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere?

The leaves* of trees and other vegetables give out during the day a large portion of oxygen gas†, which, uniting with the nitrogen gas thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere.

Is this perpetual renovation of the atmosphere owing to a fortunate concurrence of circumstances, or is it the effect of design and contrivance?

When we recollect the various processes of nature and art, which concur with respiration and combustion in depriving the atmosphere of its oxygen; and that atmospheric air, notwithstanding uniformly contains in every quarter of the globe the same proportion of this gaseous substance, we can attribute the renovation to nothing but design; and perceive in it a

* The *upper* side of the leaf is the organ of respiration; hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees, &c. shows the *importance* of transpiration to a vegetable.

To obtain oxygen gas from the leaves of plants, fill a glass bell with water, introduce leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. (Ingenhouz.) A sprig of mint, corked up with a small portion of *foul air*, and placed in the light, renders it again capable of supporting life. The plant purifies what the animal had poisoned.

For, while the vegetable tribes inhale
The genial moisture‡ from the parent vale,
Their vegetating organs decompose
The salutary compound as it flows;
Select the HYDROGEN with nicest skill,
And mould it into resin at their will.
The OXYGEN, abandoning the mass,
Combines with heat, and changes into gas;
Which, from its inmost cells, each leaflet pours
In vital currents through its myriad pores;
And thence, by *vivifying* tempests hurl'd
From pole to pole, it cheers a fainting world||. S. P.

Hales found that a sun-flower, three feet high, transpired, in 12 hours, seventeen times as much as a man.

† *All* the oxygen is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables. Mr. Cruickshank has shown by experiment, that oxygen is absolutely necessary for the conversion of mucilage into sugar. (Rollo on Diabetes.) Plants also absorb nitrogen from the atmosphere with avidity; and this is another means of keeping up the standard purity of atmospheric air.

‡ Water. || See Lavoisier's Elements, part i. chap. 6.

proof that the laws of nature must be referred, not to blind chance, but to unerring intelligence combined with infinite goodness*.

CHAPTER III.

OF CALORIC.

WHAT is heat?

Heat is the well-known sensation caused by the approach of bodies of a superior temperature†.

What name is given to the matter of heat?

Chymists have agreed to call the matter of heat *caloric*‡, in

* All kinds of vegetables, when assisted by the rays of the sun, have the power of decomposing water; during which decomposition the hydrogen is absorbed, and goes to the formation of oil and resin in the vegetable; while the oxygen combines with part of the caloric received from the sun, and is given out in the form of oxygen gas; so that this *one operation* of nature gives nourishment, and provides materials of growth to the vegetable creation, and at the same time renovates the vital principle in the atmosphere.

Nothing short of consummate wisdom could have conceived any thing half so beautiful in design, or extensively and superlatively useful in effect.

See Additional Notes, No. 10.

† The sensation of heat and cold is entirely owing to the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

For the best methods of producing artificial cold consult Mr. Walker's papers in the Philosophical Transactions for 1795 and for 1801.

‡ In answer to the question, what is the *cause* of caloric? it may be necessary to state, that philosophers have differed in their opinions on this subject. Some have considered it merely the consequence of a peculiar motion among the particles of bodies, and that it has no existence independent of motion, any more than sound has. Others have supposed that it is really a distinct substance, which exists independent of every other. The latter is the opinion of modern chymists.

order to distinguish it from the sensation which this matter produces*.

What are the uses of caloric†?

Caloric is every where indispensable to the existence of man. "It is with fire that, in every country, he prepares his food, that he dissolves metals, vitrifies rocks, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require."

What are the sources of caloric?

There are five sources from whence we procure caloric, viz. from the sun, by combustion, by percussion, by friction, and by the mixture of different substances‡.

Which of these is the principal source of caloric?

The sun is the first source which furnishes the earth with a regular supply§, and renders it capable of supporting the animal and vegetable creations||.

* In order to give precision to chymical language, it was *necessary* to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes *fixed* in a body, it loses its property of affording heat. Nothing can be more evident than that caloric may exist in many substances, without producing any of the effects which arise from the agency of fire.

† Many of the uses of fire will immediately occur to every individual, whenever the importance of this subtle fluid is alluded to; though perhaps the wisdom of the Deity, in giving the use of it to man only, has not been often noticed. But if it were at the disposal of animals, Which of our lives, or of our possessions, would be safe for a single moment? Why has this powerful agent been solely intrusted to man? Why was every fowl of heaven, and every beast of the field, impressed with an unconquerable *dread* of approaching it? It is difficult to conceive of any answer, which shall not admit or imply the wisdom, goodness, and providence, of the first cause.

‡ These are the chief sources of caloric with which we are acquainted: but there are instances of *spontaneous* combustion on record, which are unaccountable. The most remarkable case that I have seen, is related in the Philosophical Magazine, vol. xvi. 92. See also an interesting memoir on this subject, vol. xviii. 346.

Perhaps *compression* might with propriety be added to this list. See an account of Mr. Biot's Experiment, in a Note, chap. iv.; and that of the effects of the sudden compression of atmospheric air in the chapter on combustion.

§ Caloric comes to us from the sun at the rate of 200,000 miles in a second of time; but Dr. Herschel has proved, that the solar rays which produce heat are distinct from those which illuminate and produce vision.

|| According to the laws of nature, animal and vegetable life are both very much influenced by the temperature in which they exist; and accordingly we find different kinds of vegetables, and a different race of animals, appropriated to the different climates of the earth.

That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If in the midst of winter a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere. Walker, vol. i. 198.

How is caloric furnished by combustion?

The oxygen gas of the atmosphere is decomposed by combustion; and caloric, one of its component parts, is set at liberty*.

How is caloric produced by percussion?

The heat produced by percussion is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric†.

How is caloric produced by friction?

It is not known *how* friction produces caloric‡, but it is probably by the agency of electricity§.

How is caloric produced by mixture?

When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form‖; for neither water nor any other fluid can acquire an

* We are indebted to Lavoisier for the discovery that caloric is disengaged from atmospheric air by combustion: it was he who pointed this out as a general law of nature, "that in all cases of combustion, oxygen combines with the combustible, during the act of combustion." For a further explanation of this phænomenon consult the chapter on *combustion.*

† As evaporation produces cold, condensation always produces heat: that is, caloric is always evolved from those bodies which have undergone any degree of condensation. In the one case caloric is absorbed, in the other it is set at liberty.

By the collision of flint and steel so much caloric is disengaged, that the metallic particles which are struck off are actually melted thereby. This is evident, from their being always found in a *spherical* form. See Note, page 64.

‡ Mr. Thomas Wedgwood has shown, that this subject has never yet been explained. He took a piece of common window-glass, and held the edge of it against the edge of a revolving grit-stone, and the part in contact with the stone became red hot and threw off hot particles which fired gunpowder. The stone and the glass being both incombustible substances, it remains to be explaned *how* caloric was produced. Philosophical Transactions for 1792.

The original inhabitants of the New World, throughout the whole extent from Patagonia to Greenland, procured fire by rubbing pieces of hard wood against other very dry pieces, till they emitted sparks, or kindled into a flame. Some of the people to the north of California had the method of inserting a kind of pivot in the hole of a very thick plank, and by its circular friction produced the same effect. Dr. Rees's Cyclopædia.

Instances have occurred, of whole forests having been burnt down, by fires kindled from the violent friction of the branches against each other by the wind.

§ For the reasons on which this supposion is grounded consult Dr. Thomson, vol. i. 445

‖ Whenever two gases or liquids unite *chymically*, the compound has greater density than the mean density. Thus the vapour of water, at the heat of ebullition, occupies much less space than the hydrogen gas and oxygen gas which produced it, would have occupied at the same temperature. Nitrous gas has a specific gravity greater than that of the simple mixture of its two elements: it is the same with ammoniacal gas; and this latter, though its elements are already greatly condensed, experiences a new condensation

increase of density without giving out a portion of its latent caloric*.

You speak of latent *caloric; is there any difference in the nature of caloric?*

No: we have reason to believe that caloric is *always* uniform in its nature; but this term is necessary, because there exist in all bodies *two* portions of caloric, very distinct from each other†.

How are these two portions of caloric distinguished?

The one is called *sensible* heat, or *free* caloric; the other *latent* heat, or *combined* caloric ‡.

when it combines with muriatic acid gas; and this is so considerable, that both take a *solid* form. Berthollet.

* Sulphuric acid and water experience this condensation by mixture. If four parts of the former be mixed with one of the latter, the mixed fluids will quickly acquire a temperature higher than that of boiling water. It is necessary to be cautious in making this experiment.

If iron filings and sulphur be mixed into a paste with water, a sulphuret of iron will be formed, which decomposes the water and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under the ground. Encyclopædia.

Mixture does not uniformly produce heat. The mixture of some substances produces an intense cold. But the cause of both effects is easily explained. Whenever substances become more condensed by mixture, heat is evolved; when they expand, cold is produced. The mixture of muriate of lime and ice produces the greatest degree of cold yet known.

† How the same substance may exist in a body in two distinct states, may easily be explained by a piece of common bread which has been dipped in water. This bread will contain two portions of water very distinct; one of them was in a state of combination, and formed a constituent part of the bread; the other is only interposed between the particles of the bread, and may again be forced out by pressure.

‡ The difference which there is in the effects of caloric, in the two states in which it exists, may be shown by a variety of experiments. A bar of wrought iron at the *lowest* temperature we are ever accustomed to use it, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of the caloric which was in a latent state; and which by the hammering is forced out and exhibited in the form of *sensible* heat. While chymically combined with the iron, it only tended to give it malleability and ductility; but when converted to free caloric it operates with as much activity as though it had never existed in a latent state.

If a little sulphuric acid be mixed with about an ounce of nitrous acid, and the mixture be poured into oil of turpentine, the whole will burst into flame. This is owing to the compound having less capacity for caloric than these separate fluids; consequently a part of their *combined* caloric is liberated, and produces the inflammation.

The reverse of this may be shown by hanging a pan of snow over a large fire. The snow will receive a large accession of caloric from the fire without being at all sensibly warmer. The caloric as it enters becomes chymically combined, and the fire will not in the least alter its temperature, till the whole becomes fluid.

What do you mean by free caloric?

Free caloric is the matter of heat disengaged from other bodies, or, if united, not *chymically* united with them*.

What is latent caloric?

Latent caloric is that portion of the matter of heat which makes no addition to the temperature of the bodies in which it exist†.

What substances contain latent caloric?

Caloric in a latent state exists in all substances that we are acquainted with‡.

Do all substances contain the same quantity of latent caloric?

No: caloric combines§ with different substances in different proportions.

What language do chymists make use of to express the difference in this respect?

One body is said to have a greater *capacity* for caloric than another‖.

Is this capacity for caloric uniformly the same in the same bodies?

* Some writers have called the matter of heat when in this state *interposed* caloric.

† We owe to Dr. Black the discovery of *latent* heat. The train of thought and series of experiments which convinced him of this fact may be seen amply detailed in the preface to his lectures, 34 and following pages. "By this discovery we now see (as his editor expresses it) heat susceptible of fixation—of being accumulated in bodies, and, as it were, laid by till we have occasion for it; and are as certain of getting the stored-up heat, as we are certain of getting out of our drawers the things we laid up in them." —Black's Lectures, by Robison. He might have added, that whenever caloric quits its latent state, how long soever it may have lain dormant and inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

‡ Caloric pervades all bodies; this is not the case with any other substance we know of—not even light.

Caloric lies hid in every thing around us. The Creator *knew* the continual need we should have of this substance, and he has endowed it accordingly with the property of taking up its resting-place and of combining with *all* matter, however diversified may be its nature or properties. Caloric is a substance which we are ever in want of; it is therefore deposited on every side, and is ready for every exigency. Various and multiplied as are the means which have been chosen for the promotion of the general good, they are all wise and beneficent, all fully adequate to the end for which they were designed.

§ Caloric as it penetrates bodies frequently forms a chymical combination with them, and becomes essential to their composition. This is always the case when a solid is converted to a liquid, or when a liquid passes to a gaseous state. But if caloric be superadded to a body when it is in a state of saturation, it merely traverses its surface, and passes from it, in the form of sensible heat, to some of the adjacent bodies.

‖ The propriety of this term may be shown to a pupil by dipping a lock of wool and a piece of sponge in water, and directing him to observe how much more water the sponge is capable of taking up than the wool. Hence sponge may be said to have a greater *capacity* for water than wool has.

Yes: the same bodies have at all times the same capacity for caloric, unless some change takes place in the *state** of those bodies.

Can you adduce an instance of a change of this kind?

When liquid substances become solid, they lose in a great measure their capacity for caloric; and, when solid bodies become liquid, their capacity for caloric is proportionately increased†.

How does this property of bodies operate?

Whenever a body has its capacity for caloric thus increased‡,

* The nature of the combination of bodies with caloric was first placed in a clear light by Dr. Black. He discovered that all matter is subject to the following law, viz. that "whenever a body changes its state, it either combines with, or separates from, caloric."

This subject is treated with great perspicuity by Dr. Thomson in the first vol. of his System of Chymistry, to which I refer those who wish to investigate it.

If muriate of ammonia be dissolved in hot water, the temperature of the water will be found to be much lowered by the solution of the salt. When the salt takes again a solid form by crystallization, it will part with the caloric which it combined with in the act of solution, and a rise of temperature will be the consequence.

If when the air is at 22° we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole instantly rises to the freezing point; so that the water has acquired 10° of caloric in an instant. Now whence came these 10°? Is it not evident that it must come from that part of the water which was frozen, and consequently that water in the act of freezing gives out caloric?—Dr. Black. Water in a solid state has *less* capacity for caloric, than it has when in a state of fluidity.

† The freezing of water, and the cooling of melted lead, may be adduced as familiar examples of the former; and the absorption of caloric in the melting of salts will sufficiently exemplify the latter. By the solution of some salts water may be deprived of so large a portion of its caloric as to be frozen in the midst of summer. An account of several cheap and powerful frigorific mixtures may be seen in the Philos. Trans. for 1787, 1788, 1789. See also Watson's Chymical Essays, vol. iii. 139. The heat which is given out during the slaking of quick-lime, escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. The same effect is produced in making butter. When the cream changes from a fluid to a solid, a considerable degree of heat is produced.

Oxygenized muriatic acid gas becomes a *liquid* at a temperature somewhat below 40°, and at 32° forms *solid* crystals. Ammoniacal gas condenses into a liquid at—45°. Dr. Thomson, vol. i. 377.

When water is poured upon dry pulverized plaster of Paris, in order to form cornices for rooms, great heat [illegible] produced by the mixture. This is owing to the water giving out its [illegible] of fluidity as it becomes solidified in the plaster.

Whenever caloric becomes active [illegible]t; whenever it passes into [illegible]e it produces cold.

[illegible]ference in the capacity w[illegible]odies have for caloric, it

it requires a larger portion of the matter of heat to raise it to a given temperature, than another body does which has a less capacity for caloric.

Can you exemplify this curious property of matter?

If equal ~~qualities~~, by weight, of water and mercury, cooled down to the same point, be afterwards separately heated to the heat of boiling water, the water will be found to have required more than three times the quantity of caloric that the mercury did to bring it to that temperature*.

What term is made use of to denote the quantity of caloric thus required?

The portion of caloric necessary to raise a body to any given temperature is called the *specific* caloric of that body†.

Is there any method of ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for caloric?

An instrument called a *calorimeter*‡ is used for this purpose. The substances to be tried are heated to the *same* temperature,

owing to one substance having a chymical affinity for caloric superior to that of another. See this fully explained by Mr. William Henry in the fifth volume of the Manchester Memoirs.

* This property may be shown more readily by the following experiments: —Take 1 lb. of water at 100°, and mix it with 1 lb. of water heated to 200°, the mixture will be found to give the exact *mean* temperature of 150°; but 1 lb. of mercury at 100°, and 1 lb. of water at 200°, will produce a heat much higher than the *mean* temperature; which shows that mercury has not so great a *capacity* for caloric as water has; consequently it raises its temperature instead of chymically combining with it.

A metal plunged into an equal weight of water of a higher temperature, gains more degrees of thermometric heat than the water loses; and this takes place, in different proportions, for each species of metal. Berthollet.

Whenever two different kinds of substances of different temperatures are mixed, the capacity of each for caloric may be known by observing the temperature of the mixture; for the capacity of each will be in the inverse ratio of the change of temperature. But it is necessary, in order to justify this calculation, as Fourcroy has remarked, that the bodies themselves should not act chymically upon each other; and it is also necessary to prevent a portion of their caloric from being carried off by the vessels in which the experiment is made.

† This term is always used in a comparative sense, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be 1, that of water may be said to [illegible], as noted in an experiment just related.

‡ This instrument was first suggested by M. Laplace, and contrived by Lavoisier. A drawing of the machine, with an accurate description of it, may be seen in Lavoisier's Elements. Though this instrument be capable of measuring what is called the *specific* caloric of bodies, no method has yet been discovered of ascertaining the *absolute* quantity which bodies contain. It is therefore unknown at what point a thermometer would stand, if it were plunged into a substance *entirely* deprived of caloric.

and then placed in this machine surrounded with ice*. By observing how much ice each of them melts in cooling down to a given point, the specific caloric which each of them contained is determined†.

What do you call the instrument which is in common use to measure the temperature of bodies?

It is called a thermometer‡. It consists of a glass tube containing a portion of mercury, with a graduated plate annexed to it. The tube is hermetically sealed, to preserve it from the pressure of the atmosphere§.

Do you understand how a thermometer is affected by the temperature of bodies?

When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and the height at which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied‖.

* Ice has the property of absorbing all the caloric with which it comes in contact, without communicating any part of it to the surrounding bodies till the whole of the ice is melted; therefore the caloric specific of bodies may easily be calculated by its means.

† Sir Isaac Newton talks of boiling water being three times as hot as the blood in the human body. He imagined the freezing point to be the real zero, below which there was no heat. Later experiments have shown that substances may be cooled many degrees *below* the freezing point on Fahrenheit's scale. At Kamtschatka the atmosphere has been known to be 40 degrees colder than the zero of our thermometers.

‡ The thermometer was invented about the beginning of the 17th century; but it was improved, and rendered useful, by Mr. Boyle and Sir Isaac Newton.

Thermometers are made by putting mercury into small glass tubes with bulbs, and heating these bulbs till the mercury boils. This ebullition exhausts the tubes of air, and they are hermetically sealed while the mercury is boiling; which preserves the vacuum. They are afterwards graduated by a correct scale.

For very delicate experiments *air* thermometers are used, in which, as the air is expanded or contracted, a coloured liquor is made to fall or rise, which marks the degree of expansion, and consequently the variation of temperature. They are called thermoscopes.

§ Mercury, though a metal, has so great an attraction for caloric, that it absorbs sufficient to keep it in a fluid state in the common heat of the atmosphere. Owing to this affinity for caloric it expands very readily by every addition of the matter of heat. It is also equally affected by equal increments of heat at every temperature between its freezing and boiling points. Hence it is the most proper substance for thermometers.

To measure the degrees of heat in high temperature, Mr. Wedgwood contrived a very useful instrument which he called a pyrometer, a description of which may be seen in the 72d volume of the Philosophical Transactions. Si[illegible] Wedgwood's death, the method of making the pieces of clay for th[illegible]ters has been lost.

[illegible]it's thermometer is universally used in this kingdom. In it th[illegible]

Will the thermometer show the quantity of caloric in all bodies?*

No: it will not show that portion which is latent, or *chymically* combined with any body: for instance, fluids require a certain portion of caloric to keep them in a state of fluidity; which portion is *not* indicated by the thermometer†.

range between the freezing and boiling points of water is divided into 180°; and as the greatest possible degree of cold was *supposed* to be that produced by mixing snow and muriate of soda, that was made the *zero*; thus the freezing point became 32°, and the boiling point 212°.

The centigrade thermometer of France places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the name of Celsius's thermometer.

Reaumur's thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero, like the centigrade thermometer, at the freezing point.

De Lisle's thermometer is used in Russia. The graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

In Wedgwood's pyrometer the zero corresponds with 1077° of Fahrenheit's, each degree of which is equal to 130° of Fahrenheit.

For a method of reducing the degrees of one thermometer to the scale of another, consult Dr. Duncan's Elements of Pharmacy; or Lavoisier's Elements of Chymistry, p. 560, fourth edition. See a table of temperatures, according to the different thermometers, at the end of this volume, which will enable a person to form a tolerable idea of the difference there is in the scales of each.

* The property which we call the *temperature* of bodies does not show the measure of their caloric, but merely the degree of dilatation, which the caloric they contain in a disengaged state is capable of producing in the substance of which the thermometers are formed.

† Every substance requires its own quantity of caloric to raise it to a given temperature; but when raised to that temperature, every *further* addition of caloric is precisely shown by the thermometer.

If a quantity of snow be placed in a bason before a fire, and a thermometer be plunged in it, the thermometer will stand at 32°: if the thermometer be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the *same* temperature, though it has all along been receiving an accession of caloric; but the moment that the snow is all melted the thermometer will begin to rise.

In like manner, suppose a piece of ice cooled 20° below the freezing point be exposed to a hot fire with a thermometer stuck in it; the thermometer will rise very uniformly till it comes to the freezing point 32°, and there makes a full stop till the ice is all liquefied, as though the fire had lost its faculty of heating: but the moment that all the ice is melted the thermometer will begin to rise again, and will continue to rise gradually till the water becomes heated to 212°, the boiling point. These experiments show that the heat which snow and ice receive while melting is *necessary* to give them fluidity, though it does not increase their temperature; and that ice contains much less absolute caloric than water at the same temperature. Were this not the case, all cold countries would be subject to dreadful inundations; for, whenever the atmosphere became warmer than 32° the ice and snow would be melted *in an instant*, and the sudden deluge of water would sweep down every thing before it. It is pleasing to observe how careful

Is the thermometer of no use in ascertaining the temperature of fluids?

Yes: fluids operate upon the thermometer in the same manner as solids: for, whatever *free* caloric be contained in any liquid, *that* portion is accurately shown by the thermometer*.

What do you call that portion of caloric which is a necessary part of fluids?

It is called the caloric of fluidity: but different fluids require different portions of it to preserve them in the state of fluids†.

What are the effects of caloric upon bodies?

The *general* effects of caloric are to increase the bulk of the

great Author of nature hath been in providing for every exigency. To this goodness every clime and every season bear testimony.

> The tokens of HIS friendly care
> Open, and crown, and close the year.

* Nature is *uniform* in all her results; for, if we plunge a thermometer ever so often into boiling water, it will always stand at the same point, provided the pressure of the atmosphere be the same. Melting snow will always show the *same* degree upon the thermometer, in whatever state the atmosphere may be.

> " In tubes of glass mercurial columns rise
> Or sink, obedient to th' incumbent skies;
> Or, as they touch the figur'd scale, repeat
> The nice gradations of circumfluent heat."
>
> DARWIN.

† This may be made evident by the following easy experiments:—If four parts of sulphuric acid and one part of ice, both at the temperatue of 32°, be mixed together, the ice melts instantly, and the temperature of the mixture rises to 212°, the heat of boiling water. But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about—4°.3 In the *first* of these experiments, as the ice and acid combine, they become *more* dense than their *mean* density; consequently, they both give out a part of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the *other* case, the ice, assuming a liquid form, requires a large dose of caloric to give it fluidity; and the *sudden* fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can take a liquid form. See note to question 3, of chap. iv.

Bishop Watson has remarked, that nitrous acid mixed with *snow water*, excites a very great degree of heat, but when mixed with *snow* produces the greatest cold that has ever yet been observed. (Chym. Essays, vol. iii. [illegible]). These effects arise from the sames cause as the foregoing.

According to Dr. Irvine, the caloric of fluidity of

Water is - - -	140°
Spermaceti - - -	145
Bees wax - - -	175
Tin - - - -	500

substances with which it unites, and to render them specifically lighter than they were before*.

What are the particular *effects of caloric on bodies?*

It favours the solution of salts†, and promotes the union of many substances‡. In other cases it serves to separate bodies al-

* In order to be convinced that solids increase in bulk by combination with caloric, procure a piece of iron wire, of an exact length, to slip within a ring, or within some metallic box; then if the wire be heated it will be found increased in length so as not to pass through the ring or box.

From the experiments of General Roy, in the 75th volume of the Philosophical Transactions, it appears that the expansion of a steel pendulum of a clock is such, that every four degrees of the thermometer will cause a variation of a second per day; and that the difference between the going of a clock in summer and winter will be about six seconds per day, or one minute in ten days, owing to the metallic pendulum varying in length with every change of temperature. A knowledge of this circumstance gave rise to Harrison's self-regulating time-piece, which by the different expansion of *different* metals, accommodates its movements to every change of season or climate.

The expansion which heat gives to liquids may be shown by that of the spirits in a spirit thermometer; or fill a Florence flask with water to about the middle of the neck, mark the place to which it rises, and then immerse it in boiling water, when it will be seen to expand in the glass till it nearly runs over the neck of the flask.

The effect of heat on atmospheric air may be shown by tying up the neck of a bladder containing only a small quantity of air, and then bringing the bladder near a fire, where the air will become rarefied and swell the bladder to its full size.

The converse of this (viz. that the denser bodies are, the less caloric they contain,) may be shown thus:—Add one measure of water to four measures of sulphuric acid, and the temperature will rise to 300°, which is 88° above boiling water. If the mixture be now measured it will be found to measure less than it did; consequently it must have become much denser than the medium of the two separate liquors.

If 28 measures of water be mixed with 4 measures of sulphuric acid, only 29 measures of mixture will be produced instead of 32.

The best collection of facts respecting the expansion of wood by heat, will be found in a memoir by Dr. Rittenhouse, in the Transactions of the American Philosophical Society.

Some bodies are much more dilatable by heat than others. Iron is more dilatable than wood, and wood is more dilatable than a stone, Of the metals, platina dilates the least, and lead and zinc the most, by increase of tenperature.

† Put two ounces of sulphate of soda (Glauber's salt), in powder, into a tea-cup of *cold* water, the water will dissolve only a portion of it; but if heat be applied, the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot into crystals. This little experiment will have its use as an example of crystallization.

‡ Sulphur and mercury may be mixed; but if caloric be added, they combine so intimately as to form vermilion. Charcoal seems to have no attraction for oxygen in the atmospheric temperature, but if heated it unites to it with great eagerness.

ready united*; so that in the hands of chymists it is the most useful and powerful agent we are acquainted with†.

Can you recollect any other effect that caloric has upon bodies?

It is the cause of fluidity in all substances which are capable of becoming fluid‡, from the heaviest metal to the lightest gas§.

How does caloric act upon hard bodies to convert them into fluids?

It insinuates itself among their particles, and separates them from each other‖. Thus ice is converted into water, and by a further portion of caloric into steam¶.

* This is the case in distillation, whereby the most subtile parts of a compound body are dissolved by caloric, and separated from the mass in the state of gas or vapour. Every kind of distillation may be performed in a common retort, with common receivers attached to it. For strong heats, Wedgwood's retorts are much preferable to glass.

Caloric promotes the decomposition of bodies also by reason of its counteracting the attraction of cohesion which exists in all bodies.

† For a fuller explanation of the operation of caloric in chymical processes, consult the article *repulsion* in chapter xiii.

Mr. Watt mentions a strong analogy between *solution* and *fusion*: thus ice and soda have no more action on each other than soda and silex; but raise the temperature of the ice, and it unites to the soda. A sufficient increase of temperature will unite the silex also to the soda.

Potash and silex if mixed have no action on each other; but if submitted to a great heat the potash melts, and attracts the silex, which melts with it into a substance that may be dissolved in water.

It is owing to the effect of caloric in promoting solutions, that sea water in the torrid zone contains more salt than sea water in the temperate and frigid zones.

‡ Let it be remembered that all fluids are formed from solids by an addition of caloric; and that, by abstracting this caloric, solids would be reproduced.

§ For an account of the expansion of gaseous bodies by heat, see a detail of Mr. Dalton's experiments in the 5th volume of the Manchester Memoirs, p. 595; and in several papers in Nicholson's Journal. For a method of estimating the changes of volume in gases, consult Mr. Davy's memoir in the Journals of the Royal Institution.

The expansion of volatile bodies by heat may be shown by the following experiment: Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

‖ Owing to this general effect of caloric upon bodies, it has been considered as the only agent in insensible repulsion. It has been called the *repulsive power*, which constantly acts in opposition to the power of attraction, or chymical affinity.

¶ Though the temperature of *steam* be no more than that of boiling water, or 212°, yet it has been demonstrated by some very ingenious experiments Mr. Watt, that it contains near 1000° more caloric; which keeps it in form of steam. Here the caloric must be in a state of *chymical combination* with the water, or it would be indicated by the thermometer.

You say the sun is the great source of caloric: how is caloric transmitted from the sun to us?

Caloric is transmitted to us accompanied with light; both which substances are perpetually thrown off from the sun with astonishing velocity, in every direction*.

If caloric passes with such velocity, how is it retained by those substances which receive it?

It is retained by the affinity which it has for those bodies†.

What do you mean by chymical affinity?

It is owing to this principle (viz. the necessity of a large quantity of caloric being combined with fluids, to convert them into vapour or gas,) that profuse perspiration is so cooling to labouring men, and that all evaporation produces cold. A person might be frozen to death in summer by being repeatedly sprinkled with ether.

In Spain this principle is so well understood, that every family is provided with an utensil for cooling water or wine by *evaporation*. It is merely a piece of very porous earthenware, which they fill with the water; and as a small quantity is perpetually oozing through every part of the vessel, a constant evaporation from the outside is kept up, which cools the water within. The vessels are called acarrazas.

"In India and China the wealthy have their rooms open on all sides, the roof being supported on pillars, and the intervals hung with curtains. Servants without doors scatter water on these curtains continually; its evaporation absorbs a vast deal of heat, and makes the apartments cool and refreshing." Dr. Black.

* Since the discoveries of Dr. Herschel, we have reason to think that the sun is an *opaque* body, probably a habitable world; and that the light and heat we receive from it are owing to an atmosphere which it has, of elastic fluids of a phosphoric nature, by the decomposition of which, light and heat are evolved. (Philosophical Transactions 1801, 265.) Aristotle conjectured that the sun was not a body of fire. Pursuits of Literature, 2d edition, part iv. p. 96.

"Hail to that orb, from whose rich fountain flow
Beams that illume and glad the word below!
Unseen by thee, had Nature mourn'd;
No smile her Æthiop cheek adorn'd;
Pale Night had spread her spectred reign,
And death-like horror rul'd the scene." Dr. WALCOTT.

See an interesting paper on the nature and construction of the sun and fixed stars, in Philosophical Transactions for 1794.

When chymists require the most intense heat, it is procured by collecting the sun's rays by means of a double convex lens, or a concave mirror. This way of administering heat is particularly useful in operations on the gases.

† As caloric (like light) moves at the rate of 200,000 miles in a second, it never could be accumulated in any body, were it not retained by its *affinity* for that body. But for this retarding force, it would pass through the body with the rapidity of lightning, and leave not a trace behind it.

The rays of the sun seem to afford *heat*, only when they meet with an *opaque* substance, and not when they pass through a transparent one, as air-

The disposition or tendency which one substance has to unite with another substance*.

Is the chymical affinity of bodies for caloric in general very strong?

No: it is one of the weakest of all known affinities†.

How does this appear?

From the facility with which heated bodies part with their caloric to all surrounding bodies‡.

or water; or when they are reflected by a white or polished one The air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque body, as the earth for instance, heat is elicited, and is thence gradually communicated to the surrounding atmosphere. Hence, the further we remove from the earth's surface, the greater is the degree of cold. Dr. Skrimshire's Chymical Essays.

The Swiss peasants, when they want to sow their seeds, spread *black* cloths on the surface of the snow, to absorb the sun's rays and facilitate its melting.

* Before a youth can have any accurate idea of chymical attraction, the nature of philosophical attraction should be explained to him, by means of a magnet and iron filings; by globules of water, of mercury, &c.

> Hast thou not seen two pearls of dew
> The rose's velvet leaf adorn;
> How eager their attraction grew,
> As nearer to each other borne?
>
> GEO. HAY DRUMMOND.

It would be difficult to explain the nature of chymical affinity to a child, without assisting his conception by experiments. Some of the plainest, and which may be performed by a parent without difficulty, may be seen in Additional Notes, No. xi.

† It is worthy of remark, that this was wisely and kindly ordered by the Creator: for, owing to this, organized bodies have no difficulty in separating a sufficient quantity of caloric from the substances around them, and of securing to themselves the quantity necessary for their wants. It is obvious how dreadful would have been the consequences, if caloric had had as strong an affinity for bodies, as some simple substances have for each other. A small deviation from the present order of things would probably occasion infinite mischief.

> "Let no presuming impious railer tax
> Creative wisdom, as if aught was made
> In vain, or not for admirable ends." THOMSON.

"By some curious experiments Mr. John Hunter discovered that the living principle in fish, in vegetables, and even in eggs and seeds, possesses a power of resisting congelation." (Darwin). It appears that these must have some *peculiar* attraction for caloric.

‡ The facility with which caloric passes from one body to another may be owing to the repulsion which is known to exist among the particles of caloric. This repulsion gives it a tendency to fly off in every direction.

...nt Rumford has asserted, that *fluids* are non-conductors of heat; but ...urray of Edinburgh has demonstrated the contrary by experiment. ...apers in Nicholson's Journal, vol. i. 8vo. 165—241.

Is this universally the case?

Yes: it seems to be one of the laws of nature, that heated bodies should give out *part* of their free caloric to the neighbouring bodies at a lower temperature, till the whole become of an equal degree of temperature*.

The motion of caloric through bodies is of two kinds: through some bodies it moves with the same rapidity as through free space. Through other bodies it moves with a remarkably slow motion. In the first case it is said to be *transmitted* through the body, in the latter *conducted* through it. See Dr. Thomson's paper on the motion of caloric, vol. 1. 310.

* Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass is a better conductor than wood. Hence the use of wooden handles to metallic tea-pots and other utensils.

I take a piece of iron in one hand, and a piece of wood in the other; the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. How is this? The iron has a stronger affinity for caloric than wood, and conducts it from the hand much swifter than the wood, and hence gives me a more lively sense of cold.

Some of the earths are very slow conductors of heat. Sand is eminently so. "The red hot balls, employed by the garrison of Gibraltar to destroy the Spanish floating batteries, were carried from the furnaces to the bastions in *wooden* barrows with only a layer of sand interposed; and this was found sufficient to prevent the balls, though in a high state of incandescence, from setting fire to the wood." Tilloch.

The necessity of one body being endowed with a greater power to conduct caloric than another, is apparent in many instances; but perhaps the nature of snow in this respect renders us a more important service than any other substance. Owing to the distance of this globe from the sun, and to the vast mountains of ice at the poles, the atmosphere over a large portion of the earth is at times reduced to so low a temperature, that, were it not for a wise provision of nature, all vegetable life must be destroyed.

Caloric has always a tendency to equilibrium; therefore, if the temperature of the air be lowered, the earth cools in proportion: but, when the atmosphere is reduced to 32°, the water which it held in solution becomes frozen, and precipitates in the form of snow upon the earth; which it covers as with a carpet, and thereby prevents the escape of that caloric which is necessary for the preservation of those families of vegetables which depend upon it for their support and maturity. Be the air ever so cold (and in the northernmost parts of the Russian empire it is sometimes 70 degrees below the freezing point) the ground, thus covered, is seldom reduced below 32°, but is maintained equably at the temperature for the purpose above mentioned. How multiplied are the means which Nature has adopted for the preservation of all her productions!

The constant tendency of caloric to the state of *equilibrium* is very clearly expressed by Mr. John Thomson of Edinburgh. "When a mercurial thermometer," says he, "is immersed in water, the caloric of the water makes an effort to diffuse itself through the mercury, and the caloric of the mercury makes an effort to diffuse itself through the water. If the tendencies to expand be equal in these two quantities of caloric, both quantities will remain at rest. But when the tendencies to expansion are unequal, the caloric is impelled from the substance where it had existed in the state of the *greatest tension*, into the substance where it had existed in the state of the least tension. When this happens, the degree of the dilatation or contraction of the

ing of greater specific gravity, actually becomes increased in bulk, and its specific gravity continues to *lessen* as it cools.

Count Rumford noticed this fact some years ago in one of his early essays. His remarks, if I mistake not, are accompanied with some ingenious calculations, to which I refer the reader. Sir C. Blagden has, from actual observations, made a table of the specific gravity of water of different temperatures between 30 and 40 degrees.

40	1000.54 bulk.
37	1000.55
36	1000.56
35	1000.58
34	1000.60
33	1000.63
32	1000.66
31	1000.70
30	1000.74

Since these experiments, Mr. Dalton has discovered that the expansion of water is the same for any number of degrees above or below the maximum of density. Therefore the density of water at 32° and at 53° is precisely the same. The bulk of water at 5° is equal to the same bulk of water at 80°. Manchester Memoirs, vol. v. 374.

It seems from these experiments, that water becomes of less specific gravity, whether it be heated above 42°.5 or cooled below 42°.5; a fact too astonishing ever to have been discovered or imagined a priori. The wisdom and goodness of the GREAT ARTIFICER of the world in this arrangement must evidently appear, if we consider what would have been the consequences had water been subject to the general law, and, like other fluids, had become specifically heavier by the loss of its caloric. In winter, when the atmosphere became reduced to 32°, the water on the surface of our rivers would freeze and sink to the bottom; another sheet of water would freeze immediately, and sink also; the ultimate consequence of which would be, that the beds of our rivers would become repositories of immense masses of ice, which no subsequent summer could unbind; and the world would shortly be converted into a frozen chaos. How admirable the wisdom, how skilful the contrivance, that, by subjecting water to a law contrary to what is observed by other fluids, the water as it freezes becomes specifically lighter, and swims upon the surface, to perform an important service by preserving a vast body of caloric in the *subjacent* water from the effects of the surrounding cold; and to be ready to receive its own accustomed quantity upon the first change of the atmosphere!

These reflections, perhaps, will not be thought to be misplaced, should they but afford

> One ray of light in this terrene abode,
> To prove to man the goodness of his God. DARWIN.

CHAPTER IV.

OF WATER.

WHAT are the different states in which water exists?

Water is known in three states; either solid, fluid, or in vapour*.

Which of the three is the most simple and uncombined state of water?

That of ice.

What constitutes the difference between ice and water?

Water contains a large portion of caloric, which keeps it in a state of fluidity†.

* It may be remarked, that most of the substances with which we are acquainted are capable of existing in these three different states, according to the portions of caloric with which they are combined.

† Ice at 32° must absorb 140° of caloric before it can become fluid; or such a quantity as would raise a body of water of equal bulk with itself from 32° to 172°. This may be made very evident to a youth who has been taught the use of a thermometer, by the following directions:

"Take any quantity by weight of ice or snow at 32°, and mix it with an equal weight of water heated exactly to 172°. The snow instantly melts, and the temperature of the mixture is still only at *thirty-two* degrees. Here the water is cooled 140°, while the temperature of the snow is not increased at all; so that 140° of caloric have disappeared. They must have combined with the snow; but they have only melted it, without increasing its temperature. Hence, it follows irresistibly, that ice, when converted into water, absorbs and combines with 140° degrees of caloric.

Water then, after being cooled down to 32°, cannot freeze till it has parted with 140° of caloric; and ice, after being heated to 32° (which is the exact freezing point), cannot melt till it has absorbed 140° more of caloric. This is the cause of the extreme slowness of these operations. There can be no doubt, then, but that water owes its fluidity to the caloric which it contains, and that its caloric of fluidity is 140°." Thomson's Chymistry, vol. i. 365.

The advantages which we derive from the slowness of these operations, and the inconveniencies we should have suffered, had it been otherwise, are numerous and obvious. See Notes page 69 and 75-6.

What constitutes vapour?

Vapour is water, combined with an addition of 1200 degrees of caloric*.

What are the properties of vapour?

Vapour, owing to the large quantity of caloric which is combined with it, takes a gaseous form, acquires great expansive force†, and a capability of supporting enormous weights‡; whence

* However long we boil a fluid, in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated. See Note, page 48: also Additional Notes, No. iii.

Those who have an air pump may easily see that water requires a vast portion of caloric to convert it into steam; for, if a cup of *hot* water be put under the receiver, and the pump be set to work, the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat. Water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice-cold water to a boiling heat, and occupies a space 800 times greater than it does when in the form of water.

Owing to the quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold. It has been remarked before, that an animal might be frozen to death in the midst of summer, by sprinkling ether upon him repeatedly. Its evaporation would shortly carry off the whole of his vital heat. Water thrown upon a fire acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives the materials of all the heat they contain.

† The expansive force of steam is found by experiment to be much greater than that of gunpowder.

Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to this power of steam; the water of the sea finding its way to subterraneous fires. See an account of the dreadful effects of the earthquake at Catania, in the Notes to Madame de Genlis's Tales of the Castle, vol. ii. 241.

In boiling oil, the workmen are very careful to prevent any water coming near it; for a single drop coming among it would instantly, by the excessive heat of the oil, be converted into vapour, and would force part of the oil over the sides of the boiler.

It is owing to this expansive force of steam that the well-known motion in water, by boiling, is produced. The vapour is first formed at the bottom of the vessel, and, passing through the water, causes the motion in it which we call ebullition.

‡ The invention of the steam-engine was a vast acquisition to the arts. There is reason to believe that, in time, steam may be applied to many useful purposes, of which at present we have no idea. In America vessels are already navigated by steam.

"Soon shall thy arm, unconquer'd steam! afar
Drag the slow barge, or drive the rapid car,
Or on wide waving wings expanded bear
The flying chariot through the fields of air."

DARWIN.

it has become an useful and powerful agent for raising water from deep pits, and for other important purposes*.

Is water a simple or a compound substance?

Water was formerly thought to be a simple element, but it is now found to be a compound†.

What is water composed of?

Water is composed of two solid substances, united and rendered fluid by caloric‡.

What substances enter into the composition of water?

Oxygen and hydrogen§ in the proportion‖ of 85 parts by weight of oxygen, and 15 of hydrogen¶.

The steam-engine, approaching to the nature of a *perpetuum mobile*, or rather an animal, is incapable of lassitude; it procures for us coals; it works metals; moves machines; and is certainly the noblest *drudge* that was ever employed by the hand of art. Thus we "put a hook in the nose of the leviathan: play with him as with a child; and take him for a servant for ever:" thus we subdue nature, and derive aid from the elements of earthquakes. Analytical Review.

The steam-engine is brought to such perfection, that one bushel of coals will raise 6,000 hogsheads of water ten feet high, and do the work of ten horses. Where there is no waste of steam, this work may be performed *continually* with the consumption of only one bushel of coals per hour. Some of the engine chambers in London are now fitted up with great taste, and are kept with the utmost neatness; in which you may spend hours without being annoyed by the escape of the most minute portion of steam. See a more particular account of the uses of the steam-engine in Darwin's Notes to his Botanic Garden.

* Steam is now employed in a vast variety of ways in the different manufactories of this kingdom. It is used with great economy of fuel in the dye-house of Mr. Desange, in Wheeler-street, Spital-fields. Messrs. Gott and Co. of Leeds, boil 30 large coppers by the steam of one boiler. It is employed elsewhere in drying malt, linen, coffee, paper, &c. Dr. Black remarks, that steam is the most faithful *carrier* of heat that can be conceived, as it will deposit it only on such bodies as are *colder* than 212°.

† This was discovered by Mr. Cavendish, in the year 1781. Dr. Priestley had previously combined the two gases by combustion; but Mr. Cavendish was the first who drew the proper conclusion from his experiment. The benefit which the world has derived from the labours and communications of such men is incalculable. "Nature," says an elegant French writer, "in order to unite mankind by a reciprocal communication of knowledge, has given to each individual his particular ignorance; and has placed science as a common stock to render us necessary and interesting to each other."

‡ From a passage in Virgil's Georgics, lib. ii. 325, one would be tempted to believe that the ancient chymists of Egypt had discovered the composition of water. See Darwin's Botanic Garden, book i. 136.

§ Both these terms are derived from the Greek language; the former signifies *to generate acids*, the latter, *to generate water*.

‖ Hydrogen appears capable of uniting with oxygen only in *one* proportion, and *water* is the result of the composition

¶ Of all the known substances, there is not any of which an equal weight can combine with so large a portion of oxygen, covering at the same time its

How is it known that water is a compound substance?

Several methods have been contrived by chymists whereby water may be decomposed, and the exact proportion of its constituent parts ascertained*.

Do you know any of the methods of decomposing water?

Yes: it is done by passing it through a tube over red hot charcoal†, or by passing repeated electrical shocks through it‡.

Does nature decompose water in any of her operations?

Yes: water is decomposed by every living vegetable, by a secret operation peculiar to itself§. It combines the hydrogen with the carbon of the atmosphere and of the soil, to form oil||,

characteristic properties, as hydrogen; but losing also all those which characterize itself:—it requires only 15 of hydrogen to saturate nearly 85 parts of oxygen to this point. Berthollet.

As water does not permit any property of oxygen or hydrogen to be perceived, it may be concluded that these two substances are combined at the point at which the reciprocal affinity exercises the greatest effect; and that they are in a state which may be compared with that of a neutral salt, in which the acid and alkaline properties have equally become latent.

Berthollet.

* A history of the discovery of the composition and decomposition of water, with the curious facts relating thereto, may be seen detailed in a pleasing and perspicuous manner, by Mr. John Thomson, in his valuable Notes on Fourcroy, vol. i. 237, &c.

† "Water cannot be decomposed without a combustible body," or the agency of electricity or Galvanism, "as the hydrogen requires a very large dose of caloric to put it in a gaseous state. This appears from the lightness of hydrogen gas compared with water. A cubic foot of water weighs 62½ pounds, whereas a cubic foot of hydrogen gas weighs only 61 grains. This accounts for the great heat which all bodies containing hydrogen (such as oils, bitumens, and coals) give out in burning." Fourcroy.—See Additional Notes, No. xiii.

‡ One of the common modes of decomposing water is by the Galvanic pile. The method of constructing this instrument, and the mode of applying it to this purpose, may be seen in Mr. Henry's excellent Epitome of Chymistry, page 33.

Some French aëronauts decomposed water by the Galvanic pile at an elevation of near three thousand metres from the earth. Phil. Mag. vol. xix. 374

The decomposition of water by electricity or Galvanism, which produces an intense heat, seems to prove that there is a degree of temperature at which water cannot exist, but in which it is reduced to its two elelements Berthollet.—See Additional Notes, No. xv.

Water is often partially decomposed by being kept for a long time in casks, especially on long voyages. The oxygen combines with the wood, and the disengaged hydrogen imparts the disagreeable taste and smell which are observable in such water. If the cask be charred on the inside, it will not operate in this way.

§ See page 80.

|| It should always be recollected that the oil found in vegetables is produced by this *process* of vegetation. The oils, bitumens, &c. in minerals, must all have had a vegetable origin.

wax*; resin, &c.; and throws off the oxygen by its leaves;

> Killing infectious damps, and the spent air
> Storing afresh with elemental life. THOMSON.

Can you recapitulate what you have learnt of the nature of oxygen† ?

Yes: oxygen is the basis of vital air, as well as one of the constituent parts of water: it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms‡.

What is hydrogen, the other constituent part of water ?

* In Louisiana and Pennsylvania, the *myrica* is cultivated solely for the *wax* which it produces. In China, vegetable wax is extracted from plants by maceration in boiling water, and employed in the manufacture of candles.

Bees' wax is doubtless a vegetable product. The bees extract it unaltered from the leaves of trees and other vegetables. They seem, however, to mix it with some of the pollen of flowers. The comb which these insects form with the wax, is a collection of hexagonal cells closely fitted to each other. It may be remarked that no other geometrical figure could have been chosen for them, that would have been equally capacious, without any loss of room; so that the operation of infinite wisdom is apparent even in the impression of that instinct whereby these little animals are directed to fabricate their cells in that particular form and in no other.

† Nature, in economizing the primary materials of the universe, has constituted *oxygen* the basis both of the atmosphere which surrounds the earth, and of the water which forms its seas and oceans. We see in this and other instances, by what simple means the most beneficial effects have been produced.

> " For mark how oxygen with azote gas
> Plays round the globe in one aërial mass,
> Or, fused with hydrogen in ceaseless flow,
> Forms the wide waves which foam and roll below." DARWIN.

‡ Some idea may be formed of the importance of oxygen by attending to the analysis which Lavoisier made of the materials necessary for fermenting 100 pounds of sugar.

	lbs.				*lbs.*	*oz.*
Water	400	Oxygen of the water			340	
Sugar	100	Ditto of the sugar			64	
Yeast	10	Ditto of the yeast			7	12¾
	510				411	12¾
		Hydrogen of the water	60	0		
		Ditto of the sugar	8	0		
		Ditto of the yeast	1	6		
					69	6
		Carbon of the sugar	28	0		
		Ditto of the yeast	0	12½		
					28	12½
		Nitrogen in the yeast			0	¾
					510	0

It appears from the above analysis that more than four-fifths of the whole is oxygen: See a further account of oxygen in chap. x.

Hydrogen is the base of the gas which was formerly called inflammable air*.

Has any method been discovered of composing *water by a mixture of oxygen and hydrogen?*

Yes: there are several ways of doing this†; so that the composition of water is ascertained beyond all doubt‡.

Do you know any of the methods which have been employed to form water by a mixture of its constituent parts?

* Owing to the levity of hydrogen gas, it has generally been used to fill air balloons. The following is the shortest way of procuring it: Put a quantity of iron filings into a vessel which has a glass tube adapted to it, then pour upon the filings sulphuric acid diluted with 6 or 8 times its quantity of water: an effervescence will immediately take place; the water will be decomposed, the oxygen of it will become united to the metal, and the hydrogen gas will be disengaged, and may be conveyed by the glass tube into any proper receiver. Remember, hydrogen gas can be procured in no way but by the decomposition of water. See a further account of hydrogen and its compounds in chapter xi.

† Dr. Priestley seems to have been the first person who formed water from the gases in this country.

The following method of effecting the composition of water is given by Mr. Henry in his Epitome:—"Procure a glass globe capable of holding 3 or 4 quarts, and having two openings opposite to each other, which may be drawn out for a short distance like the neck of a retort. Inflame a small stream of hydrogen gas, and introduce it into the centre of the globe. The rarefied and vitiated air will ascend through the upper aperture of the globe, and a constant supply of fresh atmospheric air will be furnished from beneath. By this combustion a quantity of water will be generated, which will be condensed on the inner surface of the vessel."

An ingenious and simple apparatus for the re-composition of water has been invented by Mr. Cuthbertson. A drawing and description of it may be seen in Nicholson's Journal, i. 235, 4to.

‡ The decomposition of water and its subsequent re-formation may be shown by the following easy experiment: Mix gradually four ounces of water with one ounce of sulphuric acid in a large phial, to which add a few iron filings. The temperature of the mixture will be so much raised by the union of the water with the acid, as to enable the iron to decompose a part of the water. If a hole be neatly made through a cork which fits the mouth of the phial, and a piece of tobacco-pipe with a very small orifice be fitted into it, and the whole cemented into the phial with a mixture of resin and bees' wax, the hydrogen gas as it is separated from the water will pass in a continued stream through the pipe, and may be set on fire by the flame of a candle brought in contact with it. The gas will continue to burn with a blue lambent flame, as long as the decomposition goes on. This shows that the gas is really hydrogen, and that it arises from the decomposition of the water.

That water may be re-formed by the combustion of this gas, may be shown by holding a glass bell over it while burning. The gas as it burns unites with the oxygen of the atmosphere, and the union of the two gases produces water, which will soon be seen to deposit itself like dew on the inside of the glass. It is adviseable to fold a cloth round the bottle to prevent any injury from the fragments of glass, in case of an explosion, which sometimes will happen during this experiment, if atmospheric air be left in the phial.

Yes: if a mixture of oxygen and hydrogen gases, in proper proportion, be fired, the inflammation will unite the bases of the two gases, without separating the whole of their caloric, and *water* will be the product*.

Is there any reason to suppose that water is thus formed in any of the great operations of nature?

Yes: claps of thunder appear to be owing to a sudden combustion† of hydrogen gas and vital air; for these aërial explosions are often succeeded by an immediate torrent of rain‡.

How is the atmosphere furnished with this hydrogen gas?

Hydrogen being a component part of vegetables, it is given out in great abundance during their putrefaction, and forming a light gas it passes through the surrounding atmosphere without mixing with it§.

What is the specific gravity of water?

* In Lavoisier's Elements of Chymistry, a copper plate print of an excellent apparatus for composin water may be seen, with a full and satisfactory description of the method of making use of it.

M. Biot has succeeded in forming water from hydrogen and oxygen, by *compression* only, independently of the electric spark. The compression, by bringin the particles of gas into intimate union, makes them throw out heat sufficient to set them on fire; and the product of the combustion is *water*.

It here occurs, that the affinity of hydrogen for oxygen may be exemplified by the large portion of oxygen which all combustible bodies containing much hydrogen require in combustion; affording water as the product. Thus, one pound of highly rectified spirits of wine on being burnt will produce more than its own weight of water. See Additional Notes, No. xvi.

† This combustion is probably occasioned by lightning.

‡ The aurora borealis is probably owing to the existence of a stratum of hydrogen gas in the higher regions of the atmosphere, which being lighter than atmospheric air would keep that situation till ignited by electricity. The vulgar have had strange conceits about this curious phænomenon of nature.

> "Not so the man of philosophic eye
> And inspect sage; the waving brightness he
> Curious surveys, inquisitive to know
> The causes and materials (yet unfix'd)
> Of this appearance beautiful and new." THOMSON.

§ Hydrogen gas is only one thirteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination.

The ignis fatuus, or will-o-wisp, it is supposed, has its origin from this decomposition of decayed vegetables.

> Thus heat evolved from some fermenting mass
> Expands the kindling atoms into gas. DARWIN.

Dr. Shaw, in his Travels in Palestine, has given a curious account of an ignis fatuus which they observed there. See Shaw's Travels.

A wine pint measure of water weighs one pound*, a cubic foot of water weighs about 1000 ounces, or 62½ lbs. avoirdupois. It is 816 times heavier than atmospheric air†.

What change does water undergo in order to be converted into ice?

When the cold atmosphere has deprived water of its caloric of fluidity, crystallization takes place, and it becomes ice‡.

What do you mean by crystallization?

By crystallization is understood the concretion of certain substances into regular forms, occasioned by the loss of a portion of their caloric.

To what substances is the term usually applied?

The term is generally applied to bodies of the saline kind, and

* It is necessary for the student to bear in mind the specific gravity of water, because it is always made unity in the measure of the specific gravity of every other substance.

† This estimate is agreeably to the last experiments made by Sir George Shuckburgh, when the barometer is at 30 inches, and the thermometer between 50° and 60°.

‡ Water in freezing crystallizes in filaments which are uniformly joined at an angle of 60 degrees.

It has been said that water may be purified from the putridity which may be contained in it by *freezing*; and that in such water the portion which freezes is pure, while that which remains fluid is contaminated with noxious matter. Dr. Lamb on Constitutional Diseases.

It is owing to the *expansion* of water in freezing that rocks and trees are often split during intense frosts. According to the calculations of the Florentine academicians, a spherule of water, only one inch in diameter, expands with a force in freezing superior to the resistance of 13½ tons weight. Phil. Mag. vol. vii. 69.

This property of water is taken advantage of in splitting slate. At Colly Western the slate is dug from the quarries in large blocks, which are placed in an opposite direction to what they had in the quarry, and the rain is allowed to fall upon them; it penetrates the fissures of the slate, and the first sharp frost freezes the water, which, expanding with its usual force, splits the slate into thin layers.

It was necessary for the preservation of the world, that water should in this instance be subjected to a law different from that of other substances which change from fluid to solid. For an account of this important deviation from a general law of nature, see Note Chap. 4th, page 76.

It may be remarked, that though fresh water freezes when reduced to the temperature of 32°, sea water does not freeze till cooled down to 28.5°. Was not this designed by nature to keep the ocean open at all seasons, that there might be no impediment to that general intercourse among nations which tends so much to promote their civilization and refinement?

For this the ship, in floating balance held,
By earth attracted and by seas repell'd;
Directs her devious track through climes unknown,
That leads to every shore and every zone.

FALCONER.

to their separation, in regular and peculiar figures, from the water in which they were dissolved*.

You have said that water is composed of two solid substances; do you thence imagine that it is naturally solid?

Yes: for underneath the poles water is eternally solid; it is similar to the hardest rocks†, and may be formed by the chisel of the statuary, like stone‡.

* Crystallization is a kind of precipitation which the salt as it separates from the solvent assumes peculiar determinate forms. Mr. Smithson has shown that crystallization cannot take place while solution subsists, and that the only requisite for this operation is a freedom of motion in the masses which tend to unite. Phil. Trans. for 1803, page 27.

† There happen cracks at certain times in the ice mountain of Switzerland, which have shown the great thickness of the ice; some of these cracks have measured 300 or 400 ells deep. Near Hudson's Bay there are islands of ice which are immersed above 100 fathoms beneath the surface of the sea, and which measure three or four miles in circumference. Phil. Trans.

"There can be no doubt but that the quantity of ice at the north pole is the principal source of the coldness of our winters, and that it is brought hither by the regions of air blowing from the north." Dr. Darwin.

> Where, for relentless months, continual night
> Holds o'er the glittering waste her starry reign.
>
> Thomson.

The ice at each pole of the earth forms an immense cupola, the arch of which extends some thousand miles over the continents; the thickness of which is several hundred feet beyond the 60th degree of latitude. Navigators have assigned to detached masses, which are met with floating at sea, an elevation of from 1500 to 1800 feet. See Ellis's Voyage to Hudson's Bay.

There can be no doubt but that the thickness of these cupolas of ice is much greater nearer the poles; for astronomy sometimes presents in the heavens so vast an image of them, that the rotundity of the earth seems to be considerably affected thereby. Captain Cook could never approach nearer the south pole, where there is no land, than the 70th degree of latitude; that is, no nearer than 1500 miles; though he had coasted round it for a whole summer; and it was only under favour of a bay that he was permitted to advance even so far. St. Pierre's Studies, vol. i. 129—132.

From a late memoir by Mons. Perron, there is reason to believe that these mountains of ice at the poles, which have hitherto impeded the progress of European navigators, have been detached from the depths of the sea to float at the surface. All the results of observations made by him and other navigators concur in proving that the temperature of the sea decreases according to the depth; and that the deepest gulfs of the sea are continually covered with ice, even under the equator. A translation of this interesting memoir may be found in the 21st volume of the Philosophical Magazine.

‡ "It is related that at the whimsical marriage of Prince Gallitzin, in 1739, the Russians applied ice to the same purposes as stone. A house consisting of two apartments was built with large blocks of ice; the furniture of the rooms, even the nuptial bed, was made with ice; and the icy cannon, which were fired in honour of the day, performed their office more than once without bursting." Bishop Watson.—See Additional Notes, No. xvii.

Is this great solidity of the ice at the poles, owing to its being frozen in such large masses?

No: it is owing to its being so much divested of caloric*; for in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

Is ice the only instance of water existing in a state of solidity?

No: water becomes still *more* solid in mortars and cements, having parted with more of its caloric in that combination than it does in the act of freezing†.

What other instances are there of water taking a solid form?

Water is combined in a state of solidity in marble, in crystals, in spars, in gems, and in all alkaline and earthy salts; to all of which substances it imparts hardness, and to most of them transparency‡.

In the most northern part of the Russian territory, the cold is sometimes sufficient to freeze mercury. It is so intense in some seasons that the poor inhabitants cannot venture out of their miserable huts but at the hazard of their lives.

> There, through the prison of unbounded wilds,
> Barr'd by the hand of Nature from escape,
> Wide roams the Russian exile. Nought around
> Strikes his sad eye, but deserts lost in snow,
> And heavy-loaded groves, and solid floods,
> That stretch athwart the solitary vast
> Their icy horrors to the frozen main. THOMSON.

* We need not look for any cause for the conversion of water into ice, but the loss of its caloric; the situation or the season of the year has no influence; for "in the Grotto of Besançon, water is frozen during the heats of summer. In this singular place the variation of the thermometer between winter and summer is very inconsiderable." Madame de Genlis.

Though water be converted to ice by the loss of caloric, there is reason to suppose that ice, notwithstanding, contains more caloric than was disengaged between the state of vapour and that of congelation. See Berthollett's Statics, vol. i. 134.

I have been informed by some intelligent workers in iron and steel, that they have great difficulty in making tools hard enough to cut ice in very *cold* winters; and that in such seasons the workmen are under the necessity of having them very frequently repaired.

† Though water takes a solid form in its various combinations, such as with lime, saline crystals, &c. we know of no method of compressing it when in a fluid state. The Florentine academicians filled a globe of gold perfectly full of water, and submitted it to a very powerful press; but could not perceive that they were able to make it occupy less space than it did at first. They gave it such a degree of pressure, that at length the water exuded through the pores of the metal.

‡ Most stones and salts lose their solidity and transparency by being deprived even of a part only of the water which they contained, and generally become pulverulent. It is by a combination with water that the gases are rendered liquid substances, and that some liquids acquire the property of

What are the general and more obvious advantages which we derive from water?

Water is a necessary beverage for man and other animals; is perpetually used as a solvent * for a great variety of solid bodies†; acts an important part in conveying nourishment to the vegetable world, and giving salubrity to the atmospherical regions‡; and lastly, by its accumulation in the ocean§, affords a ready communication with distant countries;—the whole of which evidently teaches how provident the great AUTHOR of nature has been in his attentions to the *comforts and conveniencies*, as well as to the *wants* of his numerous creatures.

becoming fixed. This may be satisfactorily shown by boiling a few copper filings in concentrated sulphuric acid, with a small portion of nitric acid, till the copper is dissolved; then adding water, and leaving the mixture to cool gradually; when beautiful crystals of blue vitriol will be found, as hard as some minerals. It is the water which gives them their solidity;

> "That chief ingredient in Heaven's various works,
> Whose flexile genius sparkles in the gem,
> Grows firm in oak, and fugitive in wine." ARMSTRONG.

If water be thrown on quick-lime, it will be retained by it with such force that nothing less than an intense *red* heat will separate it. In its combination with lime it becomes much more solid than when in the state of ice, which may be proved by direct experiment. Calcined plaster of Paris, in a pulverulent state, becomes quickly solid by mixing it with water. Saussure has proved that alumine, when mixed with water, retains a tenth of its weight of that fluid at a heat which will melt iron.

* It should be remembered, that all bodies which are soluble in water, form, during their solution, a chymical combination with the water, and cannot be separated therefrom by any mechanical means. This is not the case with aqueous mixtures.

† Water is not only employed as a solvent for many solid substances, but has important uses in a variety of compounds. Besides imparting solidity to the classes of salts, it gives energy to the action of many of the acids, and is even *necessary* in their formation. Muriatic acid gas and nitrous acid gas are condensed so as to form muriatic and nitric acid only by its means.

‡ See Note, Chap. ii. page 80.

§ Some late experiments of Mr. Harrop's, related in the fifth volume of the Philosophical-Journal, render it probable that the ocean and other large bodies of water may have been designed by nature as reservoirs for supplying an increased population with the oxygen necessary for its consumption, and for producing a regular renovation of the atmosphere. The immense quantities of marine productions found at very great heights above the present level of the sea, seem to indicate that there has been a prodigious recession of the ocean. While water was conceived to be a simple and indestructible substance, innumerable conjectures were afloat as to the channels which had been found for such an immense body of water. The new chymical doctrines have afforded us a clue by which to unravel this mystery, and fresh motives for admiring the exquisite contrivance of the great Author of all things.

———————That mighty hand
That, ever busy, wheels the silent spheres,
Works in the secret deep, shoots, *steaming*, thence
The fair profusion that o'erspreads the spring. THOMSON.

See this subject further investigated in the Additional Notes, No. xviii.

I cannot resist making an extract from Mrs. Charlotte Smith's Observations on the Ocean:

"There are people who *affect* to think, nothing but the human character deserves their study, and pass over the great works of God as unworthy the trouble of contemplating. But I wonder any being who affects *taste* would venture to assert that this immense body of water presents only sameness and monotony. To me it seems, that even the colours and sounds are little less varied than those we see or hear in the midst of the most luxuriant landscape."

Ah! wherefore do the incurious say,
That this stupendous OCEAN wide
No change presents from day to day,
Save only the alternate tide?
Show them, its bounteous breast bestows
On myriads life; and bid them see
In every wave that circling flows,
Beauty, and use, and harmony.
Works of the Power Supreme who poured the flood
Round the green peopled earth, and called it good.

CHAPTER V.

OF EARTHS.

WHAT are the principal characters of an earth?

The earths in general have little or no taste; are incombustible and unalterable in the fire; unsusceptible of decomposition*;

* Baron Born is of opinion that all the earths are metallic oxides. Fourcroy thinks that we are on the point of obtaining the decomposition of these bodies.

insoluble in water, when combined with carbonic acid*, or nearly so, and of a specific gravity not greater than five times that of water†.

How many distinct earths are there?

There are nine earths known at present, viz, silex, alumine, zircone, glucine, and yttria—which are insoluble; and barytes, strontian, lime, and magnesia—which are the four soluble or alkaline earths‡.

Why are some of these earths called alkaline earths?

Barytes, strontian, and lime§ are called alkaline because they agree with alkalies in taste, causticity, solubility in water, and in their effect on vegetable colours. Magnesia agrees with the alkalies in the latter property only.

What is the nature of silex; and what are its chief properties?

* Bergman classes all substances with the earths which require more than one thousand parts of water for their solution.

† Mr. Hume, of Long-Acre, who has given various public proofs of his correct knowledge on chymical subjects, has conceived a most singular and novel opinion respecting one of these earths, namely, *Silex*. Reasoning from numberless facts and striking analogies, which every where occur, as well as from several experiments, he is led to conclude, that pure ROCK CRYSTAL is neither more nor less than OXYGEN deprived of all the caloric requisite to give it the gaseous form. As his professional duties, I know, do not allow him time to persevere in the necessary investigation of a subject of such importance, I have persuaded him to permit me publicly to announce it, that others may prosecute the inquiry.

‡ To a cursory observer the earths appear to be infinitely diversified; so much so, that he would probably think the different kinds are innumerable. However, notwithstanding the varied appearance of the earth under our feet, of that of the furrows of the field, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths; and as three of these occur but seldom, the *variety* which is produced by the other *six* becomes the more remarkable. This may fairly be adduced as one instance of the infinite skill of the Deity, as it "bespeaks an artist master of his work, acquainted with his materials."

To give a still greater variety to the works of Nature, these earths are endowed with an affinity for acids and metallic oxides, whence arise the spars, gems, and precious stones of every colour and every species.

"The unfruitful rock itself, impregn'd by thee,
In dark retirement forms the lucid stone."

THOMSON.

§ These three earths are found in nature always combined with acids. None of these combinations are very hard; either of them may be scratched with a knife. The acids which are found combined by Nature with these alkaline earths are the carbonic, the sulphuric, the fluoric, the boracic, and the phosphoric.

Silex*, or pure flint, is insoluble in water†, and in every acid except the fluoric; it endures the strongest heat without alteration‡; but, when mixed with soda or potash, becomes fusible in a strong fire, and forms glass. Its specific gravity is 2.65.

In what state is silex found native?

Silex, or siliceous earth, is found in *quartz*, in *rock crystal*, *gravel*, *sand*, and most of the *precious stones*§. It is also the chief ingredient of those stones which seem to constitute the basis of the globe.

What are the chief uses of silex?

Silex is the most durable article in the state of gravel for the formation of roads; is a necessary ingredient in earthen-ware,

* Should *pure* silex be wanted for chymical experiment, it may be procured by fusing quartzose stones with three or four times their weight of potash, dissolving the product in water, and then taking up the alkali by the addition of an acid, which will precipitate the silex which is to be washed for use. The siliceous stones should be previously heated red in a crucible, and plunged in that state into cold water. This will render them brittle, so that they may easily be reduced to powder before they are mixed with the potash.

† Though it is said water will not dissolve silex, Nature dissolves it in water by processes unknown to us. Thus stalactites and other incrustations are formed. In Iceland there is a boiling fountain which spouts water 90 feet in the air, and deposits in falling so great a quantity of siliceous earth that it forms around its base a sort of solid cup, which surmounts and envelops it.

‡ According to Saussure, quartz may be fused by a heat equal to 40.43° of Wedgwood; but this is a temperature so far above any heat that can be procured by common means, that I have not thought it necessary to alter the text.

Sand sets into a less bulk when wet, and does not afterwards contract by heat. This property may be taken advantage of in constructing furnaces, &c.

§ Mr. Kirwan in his Geological Essays, relates that about the year 1760 the emperor of Germany, being desirous to know the length of time necessary to complete a petrifaction, obtained leave from the Sultan to take up and examine one of the timbers that supported Trajan's bridge over the Danube, some miles below Belgrade. The outer part of this timber to the depth of half an inch was found to be converted to an *agate*; the inner parts were slightly petrified; and the central were still wood. The agate is a precious stone composed of silex and alumine, but chiefly silex.

Agate is brought to us from Germany in blocks. It is cut by means of diamond powder into leaves, for making caps for the pivots of mariners' needles to run in, and other purposes. Might it not be used advantageously for the balances of watches, instead of iron, which is liable to vary by magnetic influence and other causes?

Silex also constitutes two thirds of the asbestus, so valued by the ancients for wrapping up the bodies of the dead before they were committed to the funeral pile. They discovered methods of drawing the fibres of the mineral into thread, and afterwards weaving it into cloth. In consequence of its incombustibility, it preserved the ashes of the body from mixing with those of the wood upon which it was laid to be burnt. The practice was probably confined, however, to the families of the opulent. So late as the year 1702

porcelain, and cements; is the basis of glass*, and other vitreous substances†; and is an indispensable article in many of our chymical furnaces and utensils.

What is the use of silex in glass-making?

Silex is the *basis* of glass. It is rendered fusible by a due mixture of alkali, which acts as a flux to the silex, and renders the whole transparent‡.

Are these the only articles necessary to form glass?

In Holland, and some other parts of Europe, glass is manufac-

a funeral urn was discovered at Rome, in which were a scull and other remains of a human body, wrapped in a cloth of amianthus or flexible asbestus. The whole was deposited in the Vatican library.

This mineral might be manufactured into paper; and, for documents of great importance, it might perhaps be worth while to be at the expense of preparing this *incombustible* paper, and of writing upon it with indelible ink. The methods of making it into paper or cloth, and of preparing proper ink for writing upon it, may be seen in Dr. Rees's Cyclopædia. The mineral is found in Corsica; in the isle of Elba; in Sweden; and in Cornwall and the isle of Anglesea, in England.

The Chinese form furnaces with this mineral. They grind it, mix it up with some kind of mucilage, and introduce it into moulds, the form and polish of which it assumes. These furnaces are very portable, and indestructible by fire. What kind of mucilage they employ is not known; but it is said that the mucilage of gum *adraganth* answers this purpose completely.

* In order to satisfy the pupil that silex or flint may actually be fused, and that it will, with a proper combination, form glass, take 1 part of pure fine white *sand*, and 3 parts of *potash*; mix them well together, so as to form a paste; then fuse them in a crucible in a strong fire, and transparent good glass will be the product.

It would be a neater experiment to fuse it by a blowpipe; an instrument which the student should be taught to use. The best dissertation on the blowpipe will be found in Bergman's Chymical Essays.

The manufacture of glass was known very early; but glass perfectly transparent was reckoned so valuable, that Nero is said to have given 50,000*l.* for two glass cups with handles. When the excavations were made in the ancient city of Pompeii, which was buried by an eruption of Vesuvius A. D. 79. the windows of some of the houses were found glazed with a thick kind of glass, not transparent. In others isinglass was substituted, split into thin plates. Miss Starke's Letters from Italy.

The best book on glass-making, which I have seen, is an octavo volume, by H. Blancourt, with plates, 1699. But a scientific work, lately published in Paris by Loyzel, entitled "Essai sur l'Art de laVerrerie," is, I believe, the best modern work on this subject. It gives a detailed account of the different processes in this manufacture, and treats of each chymically.

† I would recommend to the perusal of the young reader, Fourcroy's account of the various uses of silex, in vol. ii. of his System of Chymistry, page 190. It is beautifully written, and cannot fail to interest and instruct the pupil.

‡ Glass cannot be made without great heat, as the alkali will not liquefy nor part with its carbonic acid and water of composition without a high temperature; and it is one of the laws of nature, (to which there are few exceptions) that, in order that two bodies may become *chymically* united, one of them must be in a state of *fluidity*.

tured with alkali and sand only; but in England, flint-glass is made by a mixture of red lead* with those substances, which gives the glass great weight, and makes it more useful for all common purposes.

What are the chief properties of alumine?

Alumine, or pure clay, is soft to the touch; adhesive to the tongue; emits a peculiar odour when moistened; forms a paste with water; will unite with most acids†; and acquires great hardness, and contracts in the fire‡. Its specific gravity is 2.

In what state is alumine found native?

This earth acquired its name from its being the basis of alum§; it is also the basis of the *clays*‖; it is found in a state of crystallization in the sapphire, and is united to the oxides of iron in the ochres; and forms also a part of most of the oriental gems.

What are the chief uses to which alumine has been applied?

* Metallic oxides have the property of making glass more fusible. The oxide of lead is serviceable in this way when mixed with glass. Plate and crown glass contain no lead.

The common bottle-glass is made with a large portion of the ashes of vegetables, or soap-boilers' waste ashes, instead of pure alkali. The portion of iron which is generally found in vegetable substances gives it the green colour.

For the *best* flint-glass rather more alkali is used than is necessary to flux the sand; and, when the whole is in fusion, the fire is continued so as to volatilize the superabundant quantity. If an extra quantity of alkali be left in the glass, it will attract water from the atmosphere, and in a short time assume a fluid state. This matter was by the old chymists called the *liquor of flint*.

‖ Professor Seigling, having left a bottle of *liquor silicum* undisturbed eight years, found transparent *rock crystal* formed in it hard enough to give fire with steel. Parkinson.—See an account of a similar result in Nicholson's Journal, vol. i. 217.

† Alumine is soluble in every acid, and in solutions of the caustic *fixed* alkalies.

‡ Alumine is completely fusible *per se* into a very hard vitreous kind of substance, hard enough to engrave with upon glass. But sufficient heat cannot be procured to effect this fusion without oxygen gas. Saussure found that it required 18.900° of Wedgwood to fuse it: but when mixed with certain proportions of silex and lime, it fuses readily.

§ *Pure* alumine may be procured by decomposing common alum with carbonate of ammonia. It has not been found native in a state of purity any where except at Halle in Germany.

‖ Common clay is a mixture of alumine and silex. It frequently contains metallic oxides, chalk, and other earths. Alumine united to the oxides of iron is gotten in great plenty in Staffordshire and Derbyshire; in which state it is called raddle, an article very useful in colour-making. Fuller's earth is alumine combined with very fine silex. It is owing to the affinity which alumine has for greasy substances, that this article is so useful in scouring cloth. Hence pipe-clay is frequently used for the same purpose. Alumine combined with carbon forms that peculiar combustible substance called *anthracite*.

Alumine is employed for various purposes, on account of its aptitude for moulding* into different forms†, and its property of hardening in the fire; such as for making bricks, earthen ware, porcelain‡, crucibles, &c. Its uses are so various and important, that we cannot conceive how man could have attained his present degree of civilization, if this earth had not been given him in abundance by Nature.

Is alumine employed in forming any chymical combinations?

Aluminous earth is employed by the dyer and the calico-printer, as a mordant for fixing various colours; and upon the continent it is artificially combined with sulphuric acid, in order to form alum§.

* Stone ware, according to the Old Testament, was known at an early period to the Jews. The making of porcelain has long been known in China and Japan; but it was accidentally discovered in Europe by a chymist, in the beginning of the 18th century. It was so esteemed by the Romans, that, after the taking of Alexandria, a porcelain vessel was the only part of the spoil retained by Augustus. Dr. Thomson, vol. ii. 286.

† Alumine is of inestimable value for securing the bottoms and sides of canals and reservoirs of water, and composes in a great measure those tenacious earths called *arable soils*.

‡ The beautiful colours which are seen upon porcelain are given by metallic oxides. Purple is given by gold; red, by the oxide of iron; yellow, by the oxide of silver; green, by copper; blue, by cobalt; and violet, by manganese.

§ In France, alum is made artificially. Chaptal, who has done so much to propagate chymical knowledge, has embarked a large capital in this trade. He has erected immense buildings, both for making alum and for preparing the sulphuric acid. See Annales de Chimie, tome iii. Repertory of Arts, vol. ii. 134.

In England it is not necessary to form alum by art, as the alum-slate is found in great abundance. It is gotten on the sea coast of the north-east part of Yorkshire, from Whitby to Stockton, a distance of about 50 miles. It is generally found in the midst of the rock. That which lies at a considerable depth is generally considered to be the best. The slate, when gotten, is broken to pieces by the aid of fire, or by exposure to the air. When the efflorescence has taken place, it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for crystallization; previous to which is added a portion of alkali, to saturate the superabundant acid, and to favour the crystallization. Indeed, alum cannot be made without a portion of ammonia or potash, as it is a triple salt. All alum is either a sulphate of alumine and potash, or a sulphate of alumine and ammonia. *Urine* is generally used in Scotland.

The *first* English alum-work was established at Gisborough in Yorkshire, in the reign of Queen Elizabeth, by Sir Thomas Chaloner, who engaged workmen from the Pope's alum-works to superintend it; and kept those workmen till his manufacture was brought to perfection, notwithstanding the bulls and anathemas which his Holiness issued in abundance against him. Beckmann's History of Inventions, vol. i. 316.

One of the most ancient manufactures of alum was at Roche, a city of Syria; whence the name of Roche-alum.

Why do potters employ a mixture of the alumine and silex in making earthen-ware?

In making earthen-ware a due proportion of both these earths is necessary; for, if alumine alone were used, the ware could not be sufficiently burnt without cracking and shrinking very much; whereas, if too much silex were used, it would be brittle and want tenacity*.

What constitutes the difference between earthen-ware and porcelain?

Porcelain is not esteemed good unless it be very compact, very white, and semi-transparent; whereas earthen-ware is opaque†. It is the semi-transparency of china‡ which constitutes the principal difference between that and earthen-ware§.

* For making pottery, or earthen-ware, the alumine is beaten in water; by which the fine parts are suspended in the fluid, while the coarser sink to the bottom of the vessel. The thick liquid is further purified by passing it through hair and lawn sieves of different fineness; after this, the liquid is mixed with another liquor of about the same density, consisting of ground flints. The mixture is then dried in a kiln, and after being beaten to a proper consistence becomes fit for being formed at the wheel into dishes, plates, bowls, &c. When the ware has been exposed to heat for a certain time, it is glazed, or is made to undergo a partial vitrification at the surface, without which it would be pervious to fluids. Ordinary pottery is glazed with a semi-vitreous oxide of lead: what is called stone-ware is glazed by the fumes of muriate of soda; that salt bein thrown into the oven during the baking of the articles, which are so disposed as to receive it on every part of their surfaces.

"Yellow or queen's-ware is made of the same substances as common pottery, but a whiter clay is used, and in different proportions. The glazing is also different. It is made by mixing in water, to the consistence of cream, 112 parts of white lead, 24 of ground flint, and 6 of flint glass. The ware, before it is glazed, is baked in the fire, by which it acquires the property of strongly imbibing moisture; it is then dipped in this composition and quickly taken out. It is afterwards exposed a second time to the fire; by which means the glaze it has imbibed is melted, and a thin glossy coat is formed upon its surface, which is more or less yellow, according as a greater or less proportion of lead has been used." Accum. The unfortunate men, who are employed in dipping the biscuit-ware in this composition, soon became paralytic from the effects of the lead; other men are substituted in their room, who are destined to labour under the same malady. Hence, the society for the promotion of the arts, &c. has offered a premium for a substitute for this glaze, or for a mode of using it which would not subject the men to these sufferings.

† It is said that a French manufacturer at Moulins, in the department of Allier, has lately discovered a new kind of earthen-ware, which comes cheap, and is capable of resisting the action of fire and acids. The glazing is purely *siliceous*, and cannot be injured by fatty substances, or by the most corrosive acids.

‡ The perfection to which the manufacture of porcelain has arrived in England is owing to the discoveries of the ingenious and indefatigable Wedgwood.

§ An interesting account of the processes which are carried on in the

What is the origin of zircone?

Zircone is a peculiar earth, which has been found only in a gem called zircon and the hyacinth of the Island of Ceylon*.

What are the properties of zircone?

Zircone, when separated from the precious stones in which it is found, has the form of a fine white powder, destitute of taste and smell. It is soluble in the acids†, but differs from all the other earths in not being soluble in the alkalies‡. Its present scarcity prevents our employing it to any useful purpose.

What is the origin of glucine?

Glucine is a peculiar earth which has been found only in the emerald and beryl, precious stones procured from Peru and from the mountains of Siberia§.

What are the properties of glucine?

Glucine, when separated from the stones which contain it, is a soft, light, white powder, without taste and smell; adhesive to the tongue like alumine; infusible by heat; but soluble in the acids, with which it forms soluble sweet-tasted salts, slightly astringent||. It has not yet come into use¶.

What is the origin of yttria?

Yttria is a peculiar earth which has been found only in a black

great French manufactory of porcelain at Sevres has been published by Brogniart, who superintends it. This paper has been translated, and published in the 13th and 14th volumes of the Philosophical Magazine.

* This earth was discovered by Klaproth, in the year 1793. The stone from which he procured it came from Ceylon; but the same stone has since been found in various parts of Europe.

A fossil from Greenland, called *compact* hyacinth, has been lately analysed, and found to contain 10 per cent, of zircone.

† If zircone be heated to whiteness, it is not afterwards soluble in the acids.

‡ If zircone be kneaded with water and gradually dried, it will take the semi transparent appearance of horn.

§ Glucine is derived from a Greek word signifying *sweet*, which is very appropriate to this earth, as it gives a saccharine taste to all the acids with which it combines.

|| This earth is insoluble in water, which is a further resemblance of alumine; but it differs from it in being soluble in the fixed alkaline *carbonates*. Alumine is soluble in *caustic* alkalies.

¶ Vauquelin is of opinion that hereafter this earth will be usefulas a mordant in dyeing, and that it may be serviceable in medicine when it comes to be discovered in greater plenty. Lelievre announced some time ago, that he had discovered the emerald in stones used for repairing the roads near Limoges in Guienne. From this source a large quantity of glucine might be procured.

From the sweet taste of the salts of glucine, we have reason to believe that Nature, who forms nothing without its use, has endowed this earth with properties which will some time or other render it eminently serviceable to the animal œconomy,

mineral from Sweden, called gadolinite; and which contains likewise iron, manganese, lime, and silex *.

What are the properties of yttria?

Yttria, when separated from the mineral, is in the form of a fine, insipid, white powder†. It forms sweet and coloured salts with the acids, is insoluble in the caustic alkalies, but easy of solution in a solution of carbonate of ammonia‡.

What is the origin of barytes?

Barytes was discovered by Scheele in a mineral called ponderous spar, and afterwards terra ponderosa§. It is chiefly found in this combination, and is very common in England and other parts of Europe.

Is this earth found in any other states?

Yes: it occurs in Northumberland, Cumberland, and Lancashire, in large masses combined with carbonic acid‖. It has

* There is some reason for supposing that yttria may be a metallic oxide. A foreign chymist has lately announced, that when muriate of yttria is heated to redness it gives out oxygenized muriatic acid.

Mr. Davy suspects that yttria and glucine are not distinct *primitive* earths, but modifications of other earths.

† The specific gravity of yttria is 4.842, which approaches nearer the specific gravity of metals than any other earth. It has therefore been said to be the link which connects the earths with the metals.

‡ Though yttria is insoluble in the alkalies, and infusible alone, it may be fused when mixed with borax, and forms a white glass with that salt.

§ Barytes was discovered by Scheele in 1774. It is always found united either with the sulphuric or the carbonic acid. The best way of procuring this earth *pure* for chymical purposes, is, to dissolve the carbonate of barytes in very weak nitrous acid; by which means the carbonic acid will be expelled, and nitrate of barytes will be formed. By exposing this nitrate of barytes to a strong heat, the nitric acid will be dissipated, and pure barytes will be left in the crucible. See Fourcroy and Vauquelin's memoir in the Annales de Chimie, xxi. 276.

Sulphuric acid is the best test for the presence of this earth.

Bergman gave it the name *barytes* from a Greek word signifying *heavy*.

Sulphate of barytes frequently occurs in the Derbyshire mines. The workmen call it cauk. For a description of this mineral, consult Thomson's Chemistry.

A method of crystallizing this earthy salt artificially was pointed out by Withering in the Philosophical Transactions for 1784.

Casciarole, an Italian shoemaker, discovered that if sulphate of barytes be calcined in a peculiar way it will acquire a phosphorescent quality, and will shine even in water. It is known by the name of Bologna phosphorus. For the method of making it consult Bouillon La Grange, vol. i. 188; or my system of Chymistry.

‖ Carbonate of barytes was first discovered by Dr. Withering of Birmingham, in the lead mines of Alston Moor, Cumberland; and for a long time afterwards it was found only there and at Anglezark, three miles to the east of Chorley, in Lancashire. Some of the specimens have much of the appearance of sulphate of alumine. See Dr. Withering's paper in the Philosophical Transactions for 1784.

been found also in France in combination with the oxide of manganese.

What are the properties of barytes?*

Barytes is of a greyish white colour; it changes the vegetable blues like alkalies†, has a pungent caustic taste, and is a violent poison. It may be known from the other earths by its solubility in water‡, by its forming an insoluble compound with sulphuric acid§, and by its tinging flame yellow. Its specific gravity is 4.00.

What are the uses of barytes?

It forms with some of the acids useful salts, which are employed as chymical re-agents‖. Combined with muriatic acid, it is employed in minute quantities in medicine. It is capable of making a very tenacious cement, but has not yet been used much in the arts¶.

What is the origin of strontian?

Strontian is a peculiar earth, discovered about the year 1787 in a mineral brought from the lead-mine of Strontian in Argyleshire. That mineral is a *carbonate* of strontian; and, as yet, has been found but in small quantities in any other place**.

Is this earth found in any other state?

* Pure barytes changes quickly when exposed to the air; it swells like quick-lime, and like it falls into a white powder; but this slacking is much more violent and speedy than that of lime. It combines intimately with water, by which combination the water becomes solidified.

† Barytes is also similar to the alkalies in changing *red* vegetable colours to a violet or blue, and *yellow* vegetable colours to a brown; in rendering oil miscible with water; in forming glass with silex; in its solubility in water; and in the readiness with which it shoots into crystals.

‡ Boiling water will dissolve half its weight of this earth, but part of it will crystallize on cooling.

§ The most singular property of this earth is the tenacity with which it holds the sulphuric acid when combined with it. It has such an affinity to it, that it will not part with it even to pure alkalies. Hence pure barytes will decompose sulphate of potash or sulphate of soda.

‖ Muriate of barytes is the best test we have for discovering the presence of sulphuric acid. A good process for forming this salt may be seen in the Journal de Phys. 1794. It has been used as a remedy for scrophulous complaints. If barytes be given in medicine, it should be used with extreme caution, as it is found to poison animals speedily, even when rendered mild by its union with carbonic acid.

¶ Barytes has been proposed as a medium for decomposing muriate of soda in a cheap way. If ever the carbonate should be found in as great masses as the sulphate of this mineral, it would undoubtedly answer the purpose completely. The method of using it may be seen in the Annales de Chimie, tom. xix. See also a paper of Vauquelin's on this subject in Journal de Phys. 1794, p. 297.

** See Pelletier's paper on this earth in the Annales de Chimie, vol. xxi. 13; and in Nicholson's Journal, 4to. vol. i. 518.

Strontian combined with sulphuric acid has been found in various parts of the world, particularly near Bristol; where it is gotten in such abundance as to be employed in the repairs of the roads in the neighbourhood*.

What are the properties of strontian?

Strontian, when separated from its acid, is of a greyish white colour†; its taste is acrid and alkaline, but less so than barytes or the alkalies. It is not poisonous; and its solution in water is capable of crystallization‡. It gives a purple colour to flame§, which is the chief characteristic that distinguishes it from barytes.

What are the uses of strontian?

Strontian, though it combines readily with all the acids and possesses alkaline properties, has not hitherto been employed for any useful purpose‖. Hereafter it may be found to possess valuable properties; for it exists in abundance, and the Author of Nature has formed nothing in vain ¶.

*What is the nature** of lime, and what are its distinguishing characters?*

Lime is of a white colour, and of a hot caustic taste; it forms salts when combined with the acids††; changes vegetable blues to a green; is incapable of fusion; gives out a great quantity of caloric when sprinkled with water; and absorbs carbonic acid when exposed to atmospheric air‡‡.

* See Nicholson's Journal, vol. iii. 36. Sulphate of strontian is found also in great plenty on the roads near Paris, and in the province of Pennsylvania in America.

† In order to procure this earth in a state of purity, carbonate of strontian may be treated in the same way as carbonate of barytes. See page 97.

‡ Strontian is not soluble in less than 100 parts of cold water; hot water dissolves it much easier; it then crystallizes on cooling.

§ If moisture be present in the mixture of strontian with inflammable bodies, the flame will be of the colour of carmine. Thus, if this earth, or the salts formed with it, are any of them dissolved in alcohol, the spirit will burn with a flame of this colour. This distinguishes it from barytes.

‖ It will be adviseable for the preceptor to procure specimens of this and other minerals, that the pupils may learn how to distinguish them. It will also serve to give a variety to the lessons, and prevent satiety.

¶ I have been informed that an eminent physician has recommended this earth as an *absorbent* to correct acidity in the stomach, when magnesia would prove too aperient.

** The specific gravity of lime is 2.3. It is soluble when pure in 700 parts of water.

†† Lime forms with sulphuric acid a compound soluble in warm water. Thus this earth is distinguished from barytes and strontian, whose sulphates are insoluble.

‡‡ The effect of carbonic acid upon lime may be shown by the f experiment: Add gradually a very small quantity of water, im with carbonic acid, to a jar about one-fourth filled with lime-w

In what state is lime found in nature?

Pure lime is not found native; it is always in a state of combination, chiefly with an acid; and more generally with carbonic acid, as in chalk, marble, limestone, &c.*

milkiness will ensue, because the carbonic acid forms with the lime an insoluble compound. On adding more of the carbonated water, and shaking the jar as these additions are made, the milkiness at last disappears, and the whole precipitate becomes re-dissolved. Hence it appears that lime, with a *small* quantity of carbonic acid, is insoluble, and soluble with a *larger* quantity.

It is thus that Nature dissolves and deposits calcareous masses. When the waters, by their exposure to the air, lose that quantity of carbonic acid which favoured the solution of the lime, deposits are formed; and hence the stalactites and incrustations found in caverns, &c. and even the foliaceous calcareous strata of rocks; which, without doubt, have in some period been held in solution. When these waters *suddenly* lose the acid which was essential to the solution, there is an *irregular* precipitation: hence those tender calcareous cellular stones, and perhaps also the spongy tufts; but if the evaporation of the carbonic acid takes place slowly, it produces crystallizations, such as stalactites, &c. Accum. When lime is crystallized by nature in combination with acids, it is called *spar*. With fluoric acid it forms the beautiful Derbyshire spar, called blue John. With carbonic acid the dog-tooth spar, the Iceland crystal, &c.

* The vast mountains of calcareous earth which are found in different parts of the world, all owe their origin, it is supposed, to the destruction of marine testaceous animals, which in long process of time formed such vast accumulated heaps.

"For in vast shoals beneath the brineless tide,
On earth's firm crust, testaceous tribes reside:
Age after age expands the peopled plain,
The tenants perish, but their cells remain;
Whence coral walls, and sparry hills ascend
From pole to pole, and round the line extend."

DARWIN.

Fourcroy, in his chymical Elements, has given a beautiful account of this process of Nature, to which I refer; as I am persuaded every reader of taste must be charmed with its perusal. See Thomson's edition, part iii. chap. 7, sect. 1.

According to Captain Cook, there are perpendicular coralline rocks (formed entirely of sea-shells) in the Southern Ocean, which are of such magnitude as to render the navigation of those seas extremely dangerous.

The shells of some testaceous animals in the South Sea are extremely large. The *kemo* shell on the coast of Sumatra is frequently found 3 or 4 feet diameter, and as white as ivory. See Marsden's History of the Island of Sumatra, page 10.

It may be remarked, that while *testaceous* shells are formed with carbonate of lime, the shells of *crustaceous* animals and the shells of birds' eggs contain also a portion of phosphate of lime. Its use in the former is not known; but the design of Nature in furnishing the shells of eggs with phosphoric acid is very apparent. The body of the egg contains neither phosphoric acid nor lime: it was necessary therefore that Nature should provide means of furnishing both these substances, which it does at the expense of the

How is pure lime procured from these minerals?

The limestone, the marble, or the chalk, is broken into convenient pieces, and piled with coal stratum super stratum in kilns, where it is kept for a considerable time in a *white* heat. By this means the carbonic acid and water are driven off, and lime is the product*.

What are the chief uses of lime?

Lime united with the acids is applied to various useful purposes, and seems destined to form a great part of the solid fabric of the terrestrial globe†. In a *separate* state it is used in many of the

shell; which becomes thinner and thinner during the whole time of incubation till the living embryo hath appropriated a sufficient quantity for the formation of its bones. Part of the albumen for this purp[illegible] combines with the shell, and another portion forms feathers, &c.

One thousand parts of egg-shells are composed of

Carbonate of lime	-	896
Phosphate of lime	-	57
Gluten and moisture		47
		1000

If fowls are kept in a state of confinement where they cannot get at any calcareous earth, they lay their eggs without shells.

* If *pure* lime is wanted for experiment, it must be preserved in well stopped bottles. Without this precaution it would soon absorb carbonic acid, and become carbonate of lime. If lime-water be exposed to the air, it soon becomes covered with a pellicle of carbonate lime from the same cause. In like manner, if a little lime-water be put into a glass syphon, and the legs of the syphon be held upwards so that a person might blow through it without the liquor running out, the breath will be found to give a milky colour to the lime-water, and lime-stone will be seen forming at the bottom of the liquor, which will effervesce with acids and have every quality that it had when in the quarry. This change is owing to the absorption of carbonic acid from the lungs.

Some persons who have occasion for lime of the *best* quality, may be glad to be informed that the earl of Stanhope has established a work on a new principle for the express purpose of furnishing this useful article in greater purity than it can be had elsewhere. See Additional Notes, No. xix.

Bishop Watson found by experiment that upon an average every ton of limestone produced 11cwt. 1qr. 4lbs. of quick-lime, weighed before it was cold; and that when exposed to the air it increased in weight *daily* at the rate of a hundred weight per ton for the first five or six days after it was drawn from the kiln. This fact is worth the notice of those farmers who fetch their lime from great distances.

In the Journal de Physique for 1775, page 311, are a plan and description of a kiln for calcining lime *after* it has been reduced to powder, in order that it might be used quite hot without the necessity of its being slacked by water. For some purposes this is found to be very advantageous.

† The inhabitants of towns and houses built on a chalky or limest[illegible] foundation are observed to be less liable to infectious or epidemic disor[illegible] than those of any other situation.

arts*, and particularly in making mortar for buildings. Also by farmers as a manure; by bleachers†, tanners, sugar-bakers, soap-boilers, and others, in their several manufactories, and in medicine‡.

How do you explain the operation of lime in forming mortars and cements?

Limestone becomes pulverulent by the loss of its carbonic acid in burning. Lime owes the property of hardening in mortar to its great attraction for water and carbonic acid. Being mixed with water, it crystallizes as it imbibes its original portion of carbonic acid, and thus by degrees becomes as hard as *unburnt* limestone§.

How does lime act so as to be of use as a manure for land?

The use of lime in agriculture seems to arise from its property of hastening the dissolution and putrefaction of all animal and vegetable matters‖; and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of plants, corn, &c.¶

* Quick-lime well dried and pulverized is said (by the French translator of Mr. Henry's Epitome of Chymistry) to increase the explosive effects of gunpowder, when mixed with twice its weight of the latter.

Lime is used in the manufacture of glue. The design of it is to prevent its becoming flexible by the absorption of moisture, and to add to its strength. Some persons use alum for the same purposes.

† Quick-lime was used by the ancients for bleaching. Theophrastus, the disciple of Aristotle, and who wrote more than 300 years before Christ, speaks of it in this connection. He relates an instance of a ship which was loaded in part with linen, and in part with quick-lime, having been set on fire by water that was accidentally thrown over the latter, which fired the linen, and occasioned the destruction of the vessel.

‡ Lime has the property of seizing oxygen from the atmosphere—hence the unhealthiness of rooms newly white-washed. Parkinson—The design of Nature in giving this property to lime is not as yet apparent.

§ When lime is made into mortar, it takes a *long time* in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than the stone.

The *sand* which is mixed with lime to form mortar or cement, serves a purpose similar to what is answered by sticks put into a saline solution to favour its crystallization: therefore, the harder and sharper the sand, the better; for, if the matter interspersed between the crystals be of a friable nature like chalk, the mortar must be weak.

For a further explanation of this chymical process see Anderson's Essays on Agriculture.

‖ Mr. Anderson thinks that no quantity of lime can possibly be too great for land.

¶ Hence lime and chalk are found to be particularly useful on sandy soils. Marle is a mixture of carbonate of lime and clay. See Additional Notes, No. xx. Marles are useful in agriculture *only* in proportion to the calcareous earth they contain. Unless they contain more than 30 per cent. of lime

What is the use of lime in the operation of tanning leather?

Lime is used by the tanner in a state of solution, in which solution the hides are immersed in order to dissolve the gelatinous part of the skin, and to facilitate the removal of the air*.

How is the lime used in the refining of sugar?

By boiling the sugar in lime-water the manufacturer deprives it of that excess of acid † which prevents its taking the solid form ‡.

What is the use of lime in the manufacture of soap?

Lime is mixed with the alkali in order to deprive it of the carbonic acid. The alkali is thus made *caustic*, and can operate more powerfully in converting the tallow into soap §.

they are of no value to the farmer. Of all the modes of trial, the one best suited to the unlearned farmer is, to observe how much *fixed air* the marle gives out; and this he will learn by dissolving a little of it in diluted muriatic acid, and observing what portion of its weight it loses by the escape of this air. Thus, if an ounce loses only 40 grains, he may conclude that the ounce of marle contained only 100 grains of calcareous earth, and that it would be his interest to pay seven times as much for a load of lime as he must pay for a load of marle at the same distance. Dr. Black's Lectures, vol. ii. 120.

Every farmer should ascertain the *nature* of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime is contaminated by magnesia, which renders it injurious to the growth of vegetables. See Mr. Tenant's paper on this subject in the Philosophical Transactions for 1799.

Magnesian limestone is generally of a fawn colour, but it may be known by its being ten times as long in dissolving in an acid as common limestone. This is the lime which the Yorkshire farmers call *hot* lime.

* The theory of tanning is shortly this: After the impurities of the skins are removed, they are steeped in an infusion of oak-bark, which consists of two distinct substances, viz. the gallic acid, and the tanning principle. The gallic acid deprives the skins of their oxygen in a gradual manner; and while this is taking place the tan combines with the fibrous part of the skins, and forms *leather*. Dr. Thomson, vol. iv. 569. See Seguin's paper on the improved modes of tanning in Nicholson's Journal, 4to. vol. i. 271.

† Lime is frequently used by chymists in processes where there is a superabundant and injurious quantity of acid. The lime seizes the acid, and frees the solution from it, by forming with it a calcareous salt.

‡ For the process of refining sugar in England, see Rees's Cyclopædia,—Article *Sugar*. The account may be relied on, as it was written by a gentleman engaged in the business.

The method of refining in the French South American colonies is described by Fourcroy, vol. vii. 215.

Dr. Roxburgh has lately published a minute account of the Hindu method of cultivating the sugar cane, in the *Asiatic Annual Register* for 1802.

§ As different alkalies require different proportions of lime to render them perfectly caustic, every soap-maker should be acquainted with a test by which he may ascertain when he had given the proper quantity.

Having paid great attention to the different processes in this manufactur- I think I am justified in saying, that no trade is less understood, even the people who conduct it, than this. At some future time I intend (if ot avocations admit of it) to draw up a treatise on the manufacture of so

We have hitherto spoken only of lime, and of carbonate of lime: is lime found native in any other state of combination?

Lime exists in large quantities in various parts of the earth combined with sulphuric acid, which forms gypsum*; with the fluoric acid in the fluor spar†; with the phosphoric acid in a mineral called *apatite*‡, and in some precious stones.

What is magnesia?

Magnesia is a very soft, white, light earth: with little taste or smell§; unalterable in the fire ||, and almost insoluble in water.¶ With sulphuric acid it forms a salt very easy of solution**.

How is magnesia procured?

Magnesia is not found in a state of purity, but is generally procured from sulphate of magnesia (Epsom salt††) which exists

in which I shall endeavour to explain the different operations on chymical principles, and how each process may be conducted to the best advantage. We have no *English* work on soap-making, and I believe there is nothing in any language worth reading on this subject except the "Report on the Fabrication of Soaps, made by Darcet, Lelievre, and Pelletier, by order of the committee of Public Safety," in the 19th volume of the Ann. de Chimie; but as the French make use of articles which our soap-makers cannot avail themselves of, a great part even of that paper is not applicable to the practice in this country.

* Gypsum is composed of 30 parts of sulphuric acid, 32 earth, and 38 water. Kirwan.

† Lime combined with the fluoric acid forms those beautiful fluor spars which are brought from the mines of Derbyshire. Combined with muriatic acid, large quantities of this earth are held in solution by the waters of the ocean.

‡ The bones of all kinds of animals are formed of this earth and phosphoric acid, in the proportion of about 80 parts earth and 20 parts acid.

The best test for the presence of lime is oxalic acid, which forms with it an insoluble precipitate. Oxalate of ammonia is generally used for this purpose.

§ Magnesia converts vegetable blues to a green. In this respect it resembles the alkalies. Indeed some chymical writers have classed it with the alkalies.

|| Though this earth is infusible of itself, it assists the fusion of every other body. It requires near 8000 times its weight of water to hold it in solution: nothwithstanding this, it has the property of rendering camphor, opium, and resins, soluble in water. Its specific gravity is 2.33.

¶ Magnesia dissolves in alkaline carbonates, but is not soluble in the caustic alkalies.

** Sulphate of magnesia is found in several mineral waters. The *bitter* saline waters generally owe their taste to this salt. All the salts formed with this earth are bitter, and generally very soluble.

The Epsom salt (sulphate of magnesia) of commerce is generally procured from the mothers which remain after the separation of common salt from sea water, by adding thereto sulphate of iron. In this process the [sul]phuric acid leaves the iron to unite with the magnesia, and the muriatic which was before combined with it unites with the iron.

† The magnesia used in medicine is prepared thus: A solution of carbo-

in abundance in sea-water, and in many springs*.

What are the uses of magnesia?

Magnesia, in a *separate* state, has important uses in medicine†. It is useful also in some chymical processes; and is employed by the manufacturers of enamels and porcelain. It is also the most effectual antidote in case of poison by the mineral acids‡.

Are there not instances in nature of the earths entering into combination with each other§?

Yes: minerals are found in which the earths are combined in different proportions by processes unknown to us, and which Nature employs to produce the variety of texture, transparency, colour, &c. visible in them‖.

nate of potash, or soda, is poured into a heated solution of sulphate of magnesia, when a double decomposition and combination take place. The sulphuric acid of the sulphate of magnesia seizes the alkali, and the carbonic acid of the alkali combines with the magnesia. Thus carbonate of magnesia and sulphate of alkali result from the process.

* Muriate of magnesia is also found in sea water. Inverary-House is built with a stone called lapis ollaris, which contains a large portion of magnesia.

Magnesia is found in talc, steatites, potstone, asbestus, fossil cork, and other minerals. The stones which contain a large portion of this earth have generally an unctuous feel, a fibrous texture, and a silky lustre

† When magnesia is taken as an aperient, it ought to be in the state of carbonate of magnesia, or what is called mild magnesia. When it is taken as an absorbent to correct acidities, calcined or caustic magnesia is most proper. On several accounts it is of consequence to attend to this distinction.

‡ If putrid water be agitated with a small quantity of magnesia, it will lose its bad taste and smell in a few minutes. Proust, Journal de Physique. Might not this method be of use sometimes at sea, on long voyages?

§ Alumine and silex are the earths which have the greatest affinity. These earths are found in nature oftener united than any other. The *hardest* stones are formed of these two earths.

Monsieur Guyton de Morveau has proved by direct experiment that the earths have not only an affinity for each other capable of producing combination, but likewise an elective attraction, which destroys one compound in order to form another. The paper containing an account of his experiments may be seen in Annales de Chimie, tom. xxxi.

Mr. Chenevix's memoir on this subject, in the Phil. Trans. for 1802, is also very interesting.

‖ Potter's clay is a mixture chiefly of silex and alumine; the colouring earths used as pigments are mixtures either of clay and the oxides of iron, or clay and charcoal; garden mould is a mixture extremely various, sometimes containing silex, alumine, magnesia, iron, lime, and carbon; the common millstone is generally composed of alumine and silex, whereas the crumbling sandstone is a mixture of iron and silex.

But it is impossible to enumerate the endless diversity of substances which Nature offers ready formed for the use of man; for the mixtures of the earths which are found *naturally* combined, comprehend all the varie[ties] of clays, slates, stones, spars, gems, rocks, crystals, zeolites, qua[rtz,] flints, &c.

A regular classification of the different earths and stones, accordin[g]

What do you suppose could be the design of Nature in forming so many distinct earths?

The earths have several properties in common; yet as every earth possesses different and specific properties, it is evident that Nature designed them for different and distinct purposes of utility.

You have enumerated the separate uses of most of the earths, can you recollect the collective advantages which arise from this class of bodies?

The uses of zircone, glucine, yttria, and strontian are not yet known; but the benefits which we derive from the other earths are too various and important to be enumerated. Besides that they afford support to the vegetable creation, they possess so many valuable properties, that man may attain a very high degree of civilization and comfort by their means.

In order to impress your memory, and to finish the consideration of this class of bodies, endeavour to recollect those uses of the earths which appear to you to be most *important.*

LIME, then, has an extensive and important use in agriculture*; it is employed in building, &c. and adds much both to the neatness and durability of our dwellings. SILEX is the basis of all mortars and cements, and is a necessary ingredient in earthen ware, porcelain, and glass. BARYTES is employed in chymical laboratories as a re-agent, and for the formation of salts. MAGNESIA, besides being the basis of several salts, is of great use in medicine; and ALUMINE, by its mixture with silex, forms vessels for chymists capable of resisting the action of the most concentrated acids; is the material of which the bricks are formed which construct the walls of our habitations, and is spread out by the great Author of nature in strata within our hills and mountains†, to arrest the progress of subterraneous waters, and

the system of M. Daubenton, may be seen in the first volume of Thomson's Fourcroy.

A few short directions for analysing stones are given in Parkinson's Chymical Pocket-book. There is an excellent paper on this subject in vol. iv. of Dr. Thomson's System of Chymistry. Fourcroy's directions are more concise, but they are worth the perusal of those who are not accustomed to this kind of analysis. Further information may be had by consulting Kirwan's Mineralogy, vol. i.

The minerals which are generally the subject of analysis with chymists are formed with different proportions of the nine earths and the metallic oxides; such as oxide of iron, copper, nickel, manganese, crome, &c.

* "The goodness of a soil depends upon its being able to retain the quantity of moisture which is proper for the nourishment of vegetables, and no more. Now the retentive power of a soil increases with the proportion of its alumine, lime, or magnesia; and diminishes as the proportion of its silex increases." Dr. Thomson.

† Some have imagined that the earth would have had more beauty, and

to produce those springs that fertilize the valleys, and which take such diversified courses upon the surface of the globe.

would have been much more convenient, if the whole had been a plane surface; and others have gone so far as to adduce the mountainous parts of the world as a proof of the imperfection of the works of Nature; but, independent of the beautiful *variety* which they give to the surface of the globe, they are the sole cause of all our springs, and the origin of rivers, without which we have a difficulty in conceiving how animal and vegetable life could have been preserved.

Like the good man who, elevated by his rank, virtues, and talents, stands erect in conscious integrity, and dispenses blessings of every kind around him—they raise their towering heads towards heaven, to draw from thence the fructifying waters; and when purified by suffering them to percolate though their siliceous beds, they pour them forth in a thousand streams to fertilize and bless every region of the earth.

I see the rivers in their *infant* beds!
Deep, deep, I hear them, lab'ring to get free!
I see the leaning strata, artful rang'd;
The gaping fissures to receive the rains,
The melting snows, and ever-dripping fogs.
Strow'd *bibulous* above, I see the sands,
The pebbly gravel next, the layers then
Of mingled moulds, of more retentive earths,
That, while the stealing moisture they transmit,
Retard its motion, and forbid its waste.

THOMSON.

When we consider that the crystal spring and the meandering river owe their origin *entirely* to these eminences dispersed over the earth's surface, what importance do they acquire in our estimation! and what reason have we to admire the wisdom of that Being who had an eye to every exigency, and in the infinity of his power has amply provided for them all!

CHAPTER VI.

OF ALKALIES.

WHAT is the nature of an alkali?*

The alkalies† have an acrid and urinous taste; they change the blue juices of vegetables to a green; and have the property of rendering oils miscible with water. They are incombustible, but may be rendered volatile by a great heat. They are soluble in water: form various salts by combination with acids‡; and act as powerful caustics § when applied to the flesh of animals ‖.

* No written description that can be given of an alkali will convey any correct idea of the taste or properties of this class of bodies to a person who has had no opportunity of examining an alkali: let the pupil therefore procure a specimen of each kind before he enters upon this chapter. The juice of the gooseberry and the lemon, and many other vegetable substances will remind him of the general properties of the acids; but having met with nothing analogous to the alkalies, it will be necessary for him to *taste* and examine one of these bodies in order to acquire any thing like a just idea of their nature. Let him form potash or soda into a neutral salt by saturating it with one of the acids, and he will perceive still more of the nature of these bodies.

† The word alkali is of Arabian origin, and signifies the "dregs of bitterness." Dr. Thomson.

‡ Potash becomes mild by its union with carbonic acid; the most caustic soda, if united to corrosive muriatic acid, forms the mild salt used at our tables.

§ It seems that causticity depends on chymical affinity, and that the caustic substance corrodes the matter to which it is applied, in consequence of its tendency to *unite* with that matter; and that it continues to act upon it until it has saturated itself by the combination. Thus the most caustic alkalies may be combined so as to form insipid salts. See Macquer's Chymical Dictionary, where this chymical operation is very fully explained.

‖ If a piece of animal flesh be put into a strong solution of potash or soda, [it w]ill immediately be acted upon by the alkali, and will soon be entirely [diss]olved thereby, so that the whole will appear as one mass.

How many alkalies are there?

There are three alkalies*; two of which have been called *fixed* alkalies, the other has long been known by the name of *volatile* alkali.

Which are the fixed alkalies?

The fixed alkalies are potash† and soda‡.

Why have they been called fixed§ *alkalies?*

Because they will endure a great heat and still remain unchanged.

What substances enter into the composition of these alkalies?

The fixed alkalies have hitherto been considered as *simple* substances, chymists not having yet been able to decompose them; but there are reasons to believe that they are compound bodies ‖.

Have we any historical account of the discovery of these substances?

Potash was known to the ancient Gauls and Germans¶; and soda was familiar to the Greeks and Hebrews This latter sub-

* The alkalies have a great affinity for water and for carbon; it is therefore probable that their causticity is owing to this circumstance, water and carbon being so abundant in animal bodies. If the alkalies be dissolved in a large portion of water, they lose their caustic qualities.

The French chymists have classed barytes, strontian, lime, and magnesia among the alkalies, on account of their possessing some alkaline properties; but as they bear a greater resemblance to the earths than the alkalies, I have adhered to the old classification of these bodies.

† Modern chymists call the pure vegetable alkali *potass*, whereas the article of commerce is called *potash*.

This alkali was formerly procured by burning vegetables in large iron pots; hence it acquired the name of *pot*ash.

‡ This alkali acquired its name from the plant *salsola soda*, which grows on the Spanish coast, and which is burnt for its preparation.

§ Mr. Chenevix objects to the term *fixed* alkalies; but as the term is used in all modern chymical writings, and as I conceive that it may be useful to assist the memory of beginners, I have retained it in this work. These alkalies have surely some claim to the title of *fixed*, for they require a [illegible]heat to dissipate them; whereas the other alkali becomes volatile at a v[illegible]ow temperature.

‖ Some time ago Guyton de Morveau imagined that he had discovered the composition of the fixed alkalies, and announced the discovery to the National Institute: but Darracq repeated the experiments of Guyton, and pointed out the fallacy of his conclusions.

I have heard only of one instance of the formation of these alkalies, though some chymists have thought they were produced in certain operations. At the great explosion of the iron furnace at Colebrook Dale by the bursting of the dam of the river, on the 7th of September 1801, its whole contents were thrown into the air, and it is said nothing was found afterwards but potash, soda, and prussiate of potash.

¶ These people were probably the *inventors* of soap, as we are told ' Pliny, that they made soap with the ashes of vegetables and tallow soap-boiler's shop with soap in it was discovered in the city of Pon overwhelmed by Vesuvius, A. D. 79. Miss Starke's Letters from Italy

stance was known to these ancients by the name of nitrum*.

What is the origin of potash?

Potash is chiefly procured by lixiviation from the ashes of burnt wood and other vegetable substances†; but as it exists in minerals and earths‡, there is reason to believe that plants receive it from the earth during vegetation§.

What is the origin of soda?

Soda is generally procured from the ashes of *marine* plants ||;

* This substance is found native in Egypt, and is there called *natron*; a name not much unlike that which it bore among the Jews and Greeks.

† A table of the quantities of alkali procured from different kinds of wood, may be seen in a valuable memoir on the fabrication of potash in Annales de Chimie, tome xix., 157. Directions, by Vauquelin, for burning vegetables in a proper manner for this purpose, will be found in the same volume, 194.

Potash is prepared in large quantities in wine countries, by the incineration of wine-lees and must. This article is known in commerce by the name of *cendres gravelées*.

‡ Potash has been discovered in the pumice-stone; in the zeolite; and in the leucite, an earth of the siliceous kind. It has also been found in the aluminous ores of La Tolfa; but never in an *uncombined* state that I know of, except in the water of some wells.

§ It has been said, that potash cannot be procured from vegetables without burning them *previously* to their being lixiviated, or treating them with nitrous acid, or by some process capable of furnishing oxygen and nitrogen: and, indeed, it has been found that, if vegetables be soaked for some time in water and then burnt, they will afford no potash. Hence it appears, that potash, or one of it constituent parts, exists in the plants *before* incineration. It is therefore probable that the potash was originally in the *soil*, and that the vegetables take it up by their vegetating organs.

|| The *salsola soda*, which grows among the cliffs on the sea coast, is endowed by nature with the property of decomposing sea-salt. By some process of vegetation, it separates the muriatic acid and absorbs the soda. Hence it acquired the name of *saltwort*. This plant is collected by the Spaniards with great care, and burnt for the manufacture of BARILLA, which is a considerable article of commerce. Thus Nature has providently furnished the inhabitant of the otherwise barren coast with a source of employment, and has enabled him to supply the interior with an article of indispensable necessity, for ages before the science of chymistry could afford him other means of decomposing muriate of soda.

"The *saltwort's* starry stalks are thickly sown,
Like humble worth, unheeded and unknown."
CHARLOTTE SMITH.

Most of the peasantry in the Shetland Isles and in the Highlands of Scotland are supported by collecting sea-weeds, and burning them into KELP, an article which produces great revenues to the lairds of those districts. The best account of this manufacture will, I believe, be found in Jameson's Min[illegible]gy of the Scottish Isles. See also Repertory of Arts, vol. xii.

The kind impartial care
Of Nature nought disdains; thoughtful to feed
Her lowest sons. THOMSON.

but the great depository of soda is the ocean, soda being one of the constituent parts of sea-salt*.

How is it that marine plants give out soda, while plants which grow in the interior of the country afford potash?

This can only be accounted for by supposing that vegetables have the power, during vegetation, of decomposing marine salt; and that they take up the soda, which is one of its component principles†.

Is soda found in any other state?

Yes: soda is found in great plenty combined with carbonic acid in the natron beds of Egypt‡, and in the East Indies§; also in various parts of the world united with other acids‖.

Soda, combined with carbonic acid, is found mixed with earth in Hungary, Bohemia, and Switzerland; also in China, Syria, Persia, and India.

* Soda is procured also by chymical processes from sea-salt, which is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, Spain, and England.

An interesting memoir on the decomposition of this salt, published by order of the Committee of Public Safety, may be seen in the Annales de Chimie, tome xix. 58. It occupies 98 pages, and contains a detailed account of several effective processes. It may perhaps be the means of saving some individuals from loss and dissappointment, if I inform them, that I have myself repeated most of those processes in a reverberatory furnace, built for that particular purpose, and sufficiently capacious to allow some hundred weights of the materials to be operated upon at once; and that I am of opinion that none of the means there directed can be profitably employed in this country during the present high price of salt, except by those whose manufactories may produce saline residuums, or whose locality of situation may give them peculiar advantages. The decomposition by potash, or by the oxides of lead, presents the fewest difficulties; but even those methods cannot be lucrative, unless at a time when potash and lead are at moderate prices.

† Can any thing be more gratifying to a well-regulated mind than the examination of these arcana of nature? "The sensualist may imagine that *he* enjoys the world; but to enjoy it *truly* is to be sensible of its greatness and its beauty."

‡ The natron lakes of Egypt annually produce a large quantity of mineral alkali. It is probably produced by means of carbonate of lime and the decomposition of muriate of soda. In summer the water of these lakes is evaporated by the sun, which leaves a bed of natron generally two feet thick; and this is broken up by wedges, &c. and packed for the European markets.

Berthollet formed an *artificial* natron bed in one of the gardens of the National Institute, by the mixture of carbonate of lime, silex, and muriate of soda. After a time, a partial decomposition was effected, which was evident from the incrustation on the surface changing the colour of test paper.

§ Large quantities of natron are frequently sold at the English East Ind' Company's public sales, which are brought by their vessels from China a other parts of the East.

‖ Soda exists native in borax, and in muriate of soda, which is our co mon culinary salt. Near Cordova in Spain there is said to be a mountai this salt 500 feet high, and nearly three miles in circumference. Dr. Th

How have the fixed alkalies been distinguished from each other?

The one has been called the *vegetable*, and the other the *mineral* alkali*.

What are the distinguishing properties of these two alkalies?

The fixed alkalies are very similar in their general properties†; but they may be distinguished by the salts which they form with different acids; and by potash being much more deliquescent than soda.

Is there any chymical test by which you can distinguish these two alkalies?

son, volume iv. 4. 2d edit.—The mine of Cracow in Poland is computed to hold salt enough to suffice the whole world for many thousands of years. Dr. Black, vol. i. 456.

Soda has also been found in the proportion of 4 per cent. in common whinstone, and in volcanic lava. Edinburgh Trans. vol. v. As these specimens contained lime and muriatic acid, it is very probable that the soda was produced by the decomposition of muriate of soda by the agency of fire.

The *chrysolite* of Greenland, which is an insoluble fluate of alumine, is found to contain 36 per cent. of soda. Klaproth.

Soda is one of the substances found in the bile of animals. Whenever this alkali occurs native, it is always in a *mild* state; and as it cannot combine with oils to form soap, unless it be *caustic*, this causticity is given it for these manufactories by artificial means. It is worthy of remark, that Nature has furnished the bile with soda in a state of *causticity*, which gives it the property of combining with and saponifying the fat or oily substances taken into the stomach, and rendering them soluble in the other animal fluids. What account can be given of this deviation from the usual course of nature, but the important purpose which it serves in the animal œconomy?

* Potash was called the vegetable alkali, because it was supposed to exist only in vegetables, though it is now found in minerals, &c. Soda was called mineral alkali, because it exists in mineral salt.

Soda, as distinguished from potash, has been known but of late years. Even half a century ago, the salt which was artificially produced by the mixture of muriatic acid and potash was called "*re-generated marine salt*;" which shows that chymists had not then learnt to distinguish between potash and soda. Some of the properties of soda were known in times of remote antiquity. A Hebrew writer speaks of washing with natron. Jeremiah, ii. 22.

† When the fixed alkalies are in a state of purity, it is impossible by inspection to distinguish them from each other; and yet they form, by union with the *same* acid, salts very opposite in their saline properties and appearance. Thus the sulphuric acid and soda form a salt very soluble in water, which crystallizes in long separate six-sided prisms, effloresces in the air, and undergoes a watery fusion by the action of heat: whereas, the same acid and *potash* form a salt extremely difficult of solution, which crystallizes in hexahedral pyramids, or in short prisms, crossing each other at right angles, is not affected by the action of the air, and decrepitates in the fire.

The oxalic acid has been used as a test to distinguish the mineral from vegetable alkali. With the latter it forms a very *soluble* salt, but with former one of difficult solubility. Kirwan's Mineralogy, vol. ii. 7.

otash may be known from soda by supersaturating it with tartaric acid, which it forms a salt very *insoluble* in water.

he alkalies, when combined with carbonic acid, form very *soluble* salts, s the earthy carbonates are nearly *insoluble* in water.

Great inconvenience has arisen to the arts for want of a convenient test of this kind. However, a solution of the ore of platina has been lately found to answer this purpose completely, as it will show immediately whether an alkaline solution contains potash or soda*.

What are the chief uses of these alkalies?

The fixed alkalies have various uses in surgery and medicine†; they are the basis of several salts; are employed much in the arts‡; and are also of great use to the analytical chymist§.

How are the fixed alkalies employed in the arts?

The fixed alkalies are used in large quantities by the glass-maker‖, the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

In a former chapter we have noticed the use of fixed alkali in making glass;—can you tell the use of it to the dyer?

The alkalies are known to have the property of altering the

* If a little of any alkaline solution be poured into a solution of the ore of platina in nitro-muriatic acid, a yellow precipitate will be seen, if the alkaline solution contained potash; but if it contained only soda, no precipitate will occur. The peculiar advantage of this test consists in its *ready* application; whereas the old test required time to ascertain the nature of the salts formed by their means.

† Fourcroy is of opinion that soda is more proper for medicinal purposes than potash, on account of its analogy with animal substances, which *always* contain it; while on the contrary no portion of potash is found in them.

‡ The greatest consumption of the fixed alkalies in this country is in the manufacture of soap. They are employed also largely in bleaching, and in the manufacture of glass. Soda and potash are both used in washing, and for other domestic purposes; as they powerfully unite with all greasy substances, and render them soluble in water.

§ See Note page 117.

‖ Soda has the property of fusing silex with more facility than potash; hence it is preferred by those glass-makers who have made trial of both these alkalies.

Soda is preferred to potash in most of the manufactures, because it is much less acrid, and is not capable, like that alkali, of attacking or weakening the texture of piece (i. e. linen) goods, nor of corroding and destroying utensils of wood, metal, &c. Fourcroy's System of Chymistry, vol. ii. 311.

It is curious to observe that the alkalies combine with *transparent* olive oil and produce soap, an *opake* mass; and that they unite with *opake* sand and produce glass, which is a *transparent* substance. How various are the properties given to those primary materials, that have been intrusted to man for the promotion of his convenience and comfort! How much is this variety calculated to gratify the inquiring mind, and to direct it to

"Look through Nature, up to Nature's, God!"

hue of most colours*: they are therefore employed with this view by the persons who are engaged in this trade.

Why are the alkalies employed in making soap?

An alkali is an essential ingredient in soap, as it is the only article capable of converting tallow or oil into a saponaceous substance, and enabling it to combine with water†.

Why are the fixed alkalies employed in making colours?

Several of the colours which are now manufactured cannot be made without an alkali: thus, animal matters are incinerated with an alkali to form Prussia blue; thus, a fixed alkali is employed as a flux in the formation of mineral blue from cobalt; also in making other mineral colours, &c.

What are the other uses of these alkalies?

* "The fixed alkalies also facilitate the solution of the colouring part of dye-goods, and render the colours darker." La Grange.

† To make soap, it is necessary to employ a fixed alkali in a caustic state. In this country the business is usually conducted in the following manner: Spanish barilla or Scotch kelp is broken in pieces, or coarsely ground by a horse mill; and when mixed with a sufficient quantity of quick-lime to absorb the carbonic acid, the whole is thrown into large wooden or iron vats, and covered with water. In large works, these vats are generally of cast iron, and sufficiently capacious to hold 3 or 4 tons of alkaline ashes. At a proper time, the water, impregnated with the caustic alkali, is let off into iron receivers below, and the vats are covered again with water, which, after standing a sufficient time, is let off as before. This liquor is called soap-boilers' lie. When a sufficient quantity of this is prepared, Russian or English tallow is put into a large iron boiler and melted with a portion of the above-mentioned alkaline lie. At first the tallow appears liquid like oil, but during its boiling it acquires by degrees consistence as it saponifies. When the alkali is uniformly combined with the tallow, the weak liquor is pumped from beneath the soap, and fresh lies are added in their stead. These are boiled as before, till the soap exhibits certain appearances well known to the manufacturer; it is then cooled down, and poured into deep wooden frames 15 inches wide and 45 inches long; where it remains till it has acquired a sufficient degree of solidity to be cut up for sale. It is the *alkali* which gives soap its detergent quality, and which renders it soluble in water. The tallow serves to moderate the sharpness of the alkali, and to prevent its injuring the hands of those who use it; which it would otherwise do.

In making yellow soap, resin is used in the proportion of about 1 part to 3 or 4 parts of tallow. The resin makes the soap more detersive, and enables the manufacturer to sell it cheaper. Common fish oil is also used in yellow soap whenever its price will admit of it.

In making soft soap, which is a distinct and separate trade in this country, potash is the alkali made use of. A solution of this alkali in a caustic state is boiled with fish oil; and when the oil is sufficiently saponified, and a complete union of the materials is formed, the *whole* is poured into small casks for sale; the water having combined with the oil as well as the alkali.

They are employed in making alum*, in bleaching, &c. &c†.

From whence is this country supplied with these alkalies?

The greatest part of the potash which is used in this country comes from America and Russia; but the kelp of our own coasts, and the barilla of Spain and Sicily‡, furnish us with most of our mineral alkali§.

Are these alkalies sold in a state of purity?

No: the potash and soda of commerce are always in combination, though not saturated, with carbonic acid‖; they are also contaminated with various earths, and sometimes with a portion of sulphur¶.

Has alkali any peculiar affinity for sulphur?

Both potash and soda have a strong affinity for sulphur: they

* Alum cannot be brought to crystallize properly without the addition of a portion of potash or ammonia. For this purpose the British manufacturers generally use kelp (which contains a quantity of potash as well as soda), or black ash, which is an article made from the waste lies of the soap-boilers, and which, with other salts, generally contains a portion of muriate and sulphate of potash. Putrid urine is sometimes used, on account of the ammonia which it affords. For the process of alum-making, see page 94.

† The design of using alkali in bleaching, is to loosen and carry off that particular substance in the cloth which occasions its brown colour, and which Dr. Home says is a kind of heavy oil. For further information consult Berthollet on dyeing.

‡ The soda of Spain is procured from the *salsola*, as has been noticed, and also from the *batis maritima*. This Sicily barilla which is imported into this country is chiefly made by the incineration of the *zostera maritima*.

§ As we are indebted to foreign countries for most of our fixed alkalies, it would be a great national benefit if some ingenious chymist could discover an expeditious as well as œconomical mode of recovering the alkalies after they have been used for manufacturing or domestic purposes. The waste liquor might be evaporated; and if the residuum were calcined, the potash or soda would be recovered entire, and endowed with all the valuable properties which it originally possessed; as it is by nature indestructible. The desideratum is, how to divest it of its impurities, and how to calcine it at a small expense.

By examining "The Report of the Committee of the House of Commons appointed to inquire into the Laws relating to the Salt Duties," I find that from the 5th of Jan. 1800 to the 5th of Jan. 1801 the following quantities of alkali were imported into Great Britain:

	Cwt.	*Declared Value.*
Barilla	172,454	£. 362,153 18 6
Pearlash	44,401	128,765 2 6
Potash	135,401	284,342 3 6

‖ The potash and soda of commerce contain nearly one 5th of their weight of carbonic acid, besides lime, silex, and other impurities.

¶ An ash which contains 20 per cent. of pure alkali is capable of taking up 15 parts of sulphur. Such ashes may be desulphurated by thre cesses: by calcining them in an open furnace exposed to a rapid

combine by trituration or heat, and form *sulphuret* of alkali*, formerly called *hepar sulphuris*, "liver of sulphur."

What is the nature of sulphuret of alkali?

Its colour is similar to that of the liver of animals; its taste is acrid and bitter; and it has the property of decomposing water†.

How are the alkalies of commerce purified for the use of the chymist or the manufacturer?

Potash or soda is generally mixed with a portion of quicklime to divest it of carbonic acid, and then lixiviated in proper vessels to obtain a solution of the caustic alkali, free from other impurities. When it is required *perfectly* pure for nice purposes, the alkali is dissolved in alcohol, and purified by a peculiar process‡.

Are the fixed alkalies ever used in a state of combination with carbonic acid?

Carbonic acid gives potash and soda the property of crystallizing readily§: it also renders these alkalies mild||, and fit for purposes

air; by saturating them with any vegetable acid; or by exposing them in a situation to imbibe carbonic acid. Irish Transactions, 1789.

* If equal parts of sulphur and potash are triturated together in a mortar, the sulphur will soon acquire a green colour, the temperature of the mixture will be raised, and a *sulphuret of potash* will be formed.

Carbonate of potash or soda will answer for this purpose as well as the pure alkalies; for the heat which is given out by the mixture, enables the carbonic acid to pass off in the form of gas.

Sulphuret of potash or soda cannot exist but in a *dry* state. When dissolved in water it becomes decomposed, and sulphuretted hydrogen is formed.

† If sulphuret of potash or soda be moistened with water, it emits a gas extremely fœtid, decomposes a part of the water, and becomes *hydrogenized sulphuret of soda or potash*, owing to its union with a portion of sulphuretted hydrogen, arising from the decomposition of the water.

‡ The different methods which have been made use of to purify the fixed alkalies, are detailed at length by Mr. John Thomson in his Notes on Fourcroy, vol. i. 373.

Another method of purifying the fixed alkalies has been suggested by Nowitz, which may be seen in Nicholson's Journal, vol. i. 4.

Mr. Henry has suggested that the fixed alkalies may be purified from sulphate of potash, which generally contaminates them, by means of barytes. His method consists in rendering the alkali first perfectly caustic by quicklime, and then adding to the clear solution a warm solution of pure barytic earth till the precipitation ceases. The barytes seizes the sulphuric acid, and leaves the alkali pure; which may, if required, be afterwards saturated with carbonic acid, in any of the common modes. During its restoration to a mild state, any barytes that may remain in excess is also precipitated.

§ Carbonate of soda crystallizes very readily, and by proper management crystals of a lage size may be procured. Carbonate of potash is not very easily crystallized unless it be *saturated* with carbonic acid, which is never the case unless aturated by art.

|| Caustic corrosive that it will corrode glass vessels in which it is kept, em brittle, like earthen-ware half burnt.

which they would be unfit for in a caustic state*. Hence carbonic of potash is employed in medicine, and carbonate of soda for washing and other domestic uses.

What is the chymical name of volatile *alkali?*

It is called ammonia.

What are the properties of ammonia?

Ammonia is urinous and caustic; but it does not corrode animal substances like potash or soda. Its most simple state is that of gas†. In some of its combinations it is so extremely volatile, that it will bear no degree of heat without being dissipated‡.

As this alkali is a gaseous substance; how has it ever been applied in the arts?

Ammonia has an affinity for water§, with which it readily combines, and forms *liquid* ammonia; in which state it is generally used‖.

What is the composition of ammonia?

Ammonia is a compound of hydrogen and nitrogen in the proportion of about two parts of the former, and eight of the latter¶.

* Carbonate of soda and carbonate of potash are of use in chymical laboratories as *re-agents*, being employed for purposes which could not be effected by the *caustic* alkalies. Thus the two fixed alkaline carbonates will precipitate barytes, strontian, lime, magnesia, manganese, and iron, from their solutions. This they effect by means of double decomposition. But when these re-agents are employed to precipitate either of the three latter substances, if too much be used the precipitate will be *re-dissolved*: some nicety therefore is requisite in separating magnesia, manganese, and iron, from their solutions by this means.

† Ammoniacal gas is lighter than atmospheric air in the proportion of 3 to 5: it is, like it, elastic and invisible; but it causes the death of animals that are obliged to breathe it.

‡ Ammonia has another property peculiar to it, viz. that of reducing the oxides of metals to a metallic state. Ammonia being composed of hydrogen and nitrogen, the hydrogen seizes the oxygen from the metal and forms water, while the nitrogen escapes in a gaseous form. Some metals are oxidized and dissolved by liquid ammonia.

§ Water is incapable of dissolving either hydrogen or nitrogen, and yet when these are united in ammonia their nature is so changed that they become very soluble in water.

‖ Owing to the levity of ammoniacal gas, the water becomes specifically lighter as it combines with it. Hence its solution is always *lighter* than water.

A cubic inch of ammoniacal gas weighs only 0·27 parts of a grain, while atmospheric air weighs 0·46.

¶ One thousand parts of ammonia consist of 807 parts of nitrogen, and 193 parts of hydrogen. This is the result of experiment; we have therefore an accurate knowledge of the composition of this alkali.

By the following process ammonia may be formed, so as to become evident to the senses in a short time: Take some filings of tin or zinc, pour on them some moderately dilute nitrous acid. After a short time stir in

Is this alkali capable of being decomposed?

Yes: ammonia may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat—and nitrous acid and water will be the result*. If passed over red-hot charcoal, it will combine with part of the charcoal and form *prussic acid.*

How is ammonia procured?

All animal and vegetable substances will furnish ammonia when in a state of putrefaction†; but this alkali is procured in England chiefly by a dry distillation of bones, horns, and other animal substances‡.

mixture some quicklime, or caustic alkali, and a very strong pungent smell of ammonia will be produced. For the rationale of this experiment consult Dr Rees's New Cyclopædia, article *ammonia*. See also Higgins on Ammonia, and a curious paper by Dr. Milner, in the Philosophical Trans. vol. lxxix. 300.

Though the nature of ammonia is well known, we have not been able as yet to form it by a *direct* combination of its constituent principles.

* Dr. Priestley was the first chymist who decomposed ammoniacal gas; but I believe Berthollet was the first who proved its composition by synthesis as well as analysis.

The decomposition of ammonia may be shewn by the following experiment: Fill four-fifths of a long glass tube with strong oxygenized muriatic acid, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the oxygenized muriaatic acid; but by its passing a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

In this experiment the oxygen of the oxygenized muriatic acid combines with the hydrogen of the ammonia, and forms water; while the other component part of the ammonia, nitrogen, becomes disengaged in the form of gas. When the oxygenized muriatic acid is thus reduced to common muriatic acid, it unites with another part of the ammonia, and forms with it muriate of ammonia. Accum, vol. i. 315. I believe this experiment was first shown by Mr. Davy, at the Royal Institution.

† As the quantity of ammonia obtained from different substances corresponds with the quantity of nitrogen which they contain, and knowing that ammonia is one of the products of putrefaction, it has occurred to me that a manufacture of volatile alkali might be established with advantage on any part of the coast where herrings, pilchards, &c. arrive in such shoals as to be employed in manure for land. Besides, as fish bones contain more phosphoric acid than those of quadrupeds, the bones might be advantageously employed afterwards in the manufacture of phosphorus, &c.

‡ Ammonia is also found in mineral waters. According to Dr. Austin, ammonia is formed whenever iron rusts in water which has a free communication with the air. Phil. Trans. vol. lxxviii, 379.

For chymical experiments ammoniacal gas may be procured thus:—Mix one part of powdered sal ammoniac with two parts of powdered quick-lime in a retort, and apply the heat of a lamp, which will disengage the gas in ab[illegible] On account of its affinity for water, the gas must be received r[illegible].

[illegible]al gas may be procured also by heating liquid ammonia, and [illegible] gas as before.

What are the uses of ammonia?

In a liquid state ammonia has various uses in our manufactories*, and in medicine†; it is a valuable re-agent to the chymist‡; and when combined with carbonic acid it takes a concrete form and a beautiful white colour, being then the article known in commerce by the name of *volatile salts* §.

Are there any other ‖ *uses to which ammonia is applied?*

Ammonia is serviceable in dyeing, and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

How is ammonia formed into muriate of ammonia?

Muriate of ammonia is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac* ¶.

Muriatic or acetic acid are the usual tests employed to discover the presence of ammonia. If either of these be held over aqua-ammonia, white fumes will appear, which are owing to the ammonia uniting with the acid, and forming therewith a neutral salt in a visible form.

* Ammonia is of use in making archil, an article in great demand with the dyers. A Florentine merchant about the year 1300, having accidentally observed that urine, which contains ammonia, imparted a very fine colour to a certain species of moss, he made experiments, and learned to prepare archil. Berthollet.

† Ammonia is a valuable medicine where the humours are too much oxygenized. It speedily produces great weakness in the animal organs.

‡ The uses of ammonia to the chymist are many and important: hardly any complete analysis can be made without it. It discovers the presence of copper in solution, by imparting a *blue* colour to the solution.

It is said that this alkali will give to *new* brandy all the qualities of that of the oldest date. The method consists in pouring five or six drops of aqua-ammonia into each bottle of brandy, and shaking it well; which combines with the acid, on which the taste and other qualities of the new liquor depend. Bib. Phys. Econ.

§ When ammoniacal gas is passed into carbonic acid gas, the two gases become condensed, and a crystallization of carbonate of ammonia, in silky fibres or fine powder, takes place upon the internal surface of the vessel.—This is a beautiful experiment; but it must be made over mercury, and not upon water, as water will absorb the ammoniacal gas.

‖ It has lately been discovered that ammonia is useful in vegetation. See Dr. Darwin's Treatise on Agriculture and Gardening.

Muriate of ammonia has been found native in the neighbourhood of volcanos; in some of the mountains of Tartary and Thibet, and in the waters of some lakes in Tuscany.

¶ In Great Britain aqua-ammonia is saturated with sulphuric acid, which form sulphate of ammonia. This is decomposed by muriate of soda, from which result muriate of ammonia and sulphate of soda. The former is sublimed into cakes, and the latter crystallized for Glauber's salt.

In France a very considerable manufactory of sal-ammoniac was established a few years ago, on a plan very different to the usual practice. Leblanc de Franciade was the author of the process. He covered the brick floor of an oven heated to redness, with common salt, and poured thereon sulphuric acid. The muriatic gas which arose was conducted by a brick gutter into a large leaden chamber, where it met with a stream of ammoniacal gas, conducted

Muriate of ammonia being formed by two gaseous substances, how does it acquire solidity?

It may appear surprising that the union of two gases should produce a hard ponderous body; but this may be attributed to their loss of caloric. The bases of these gases having a greater affinity for each other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced*.

What are the uses of sal-ammoniac?

Sal-ammoniac is used in many of our manufactories, particularly by dyers, to give a brightness to certain colours†; also by braziers, tinplate-workers, and others; and in medicine.

From whence was salammoniac procured before it was made in this country?

Sal-ammoniac was formerly brought from Egypt sufficient for the supply of all Europe‡; but it is now made in various parts

thither from animal matters burning at the same time in three iron cylinders, placed in a furnace beside the former. These gases condensed by mixture, which was hastened by an eolipile heated by the same furnace.

A full account of the process may be seen in Annales de Chimie, tom. xix. 61: it will, however, be better understood by examining a drawing of the apparatus in one of the volumes of the Journal de Physique; but not having at present access to that work, I cannot point out the volume in which it may be seen.

Sal-ammoniac is very profitably formed in France also by the distillation of animal substances, and mixing the aqueous product with the mother-waters of the saline springs of La Meurth, Mount Blanc, &c. which contain muriate of lime and muriate of magnesia. By this mixture a double decomposition takes place, and the carbonates of lime and magnesia, being insoluble, precipitate, while the muriate of ammonia remains dissolved. The latter solution is then evaporated to dryness, and the salt sublimed for sale. See Annales de Chimie, tom. xx. 186.

* This mixture may be considered one of the most striking chymical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances we know of; they are so volatile and gaseous that neither of them can be condensed when in a state of purity; and yet these gases are no sooner thrown together than they form a *solid* and *inodorous* substance, void of volatility, aud of little taste.

† Sal ammoniac is used also by dyers in what they call composition, it is employed to prevent the tin from precipitating. In tinning metals it is used to cleanse the surfaces, and to prevent them from oxidizing by the heat which is given to them in the operation. This salt is used also in the assay of metals, to discover the presence of iron.

‡ Sal-ammoniac acquired its name from the Temple of Jupiter Ammon, it being first made in the neighbourhood of that temple. According to Pliny, [t]here were large inns in the vicinity of this famous temple, where the pil[gr]ims who came to worship, lodged; and who usually travelled on camels. [Th]e proprietors of these stables had some contrivance for preserving and [con]centrating the urine of these beasts, and the salts which it produced [wer]e afterwards sublimed in glass vessels for sale. Pliny, lib. xxxi. ch. 7.

of Great Britain, particularly in Scotland, where it is formed by a peculiar process from soot.

Is ammonia capable of entering into any other combinations?

Yes: ammonia is capable of forming salts with the sulphuric, nitric, fluoric, and most other acids*.

Can you recapitulate the origin of the different alkalies?

Yes; the volatile alkali is procured from bones and other animal matters; the vegetable alkali from the ashes of weeds and burnt wood; and the mineral alkali from sea-salt†, or muriate of soda, and the ashes of marine plants.

What is the natural inference from a consideration of the nature and production of the alkalies?

The reflection which naturally arises from a consideration of this subject, is, that the pristine organization of matter, whereby the effete recrementitious parts of animals and vegetables are made capable of producing useful and powerful substances, evinces, that infinite Power and Wisdom, conjoined with consummate Beneficence, can effect the most *important* changes, by the most *unlikely* agents; and can convert to valuable purposes, substances which to *us* appear totally useless and inert‡.

* If ammoniacal gas be brought in contact with either of the acid gases, they both lose their aëriform appearance, and a solid salt is produced. These salts are called *ammoniacal* salts. For an account of their properties consult the chapter on Salts.

† Soda may readily be procured from muriate of soda, common salt, by methods alluded to, page 111. As the act of parliament which imposes the tax upon salt, allows it to be used duty free for the separation of mineral alkali, to be consumed in making glass, a manufacture of soda has within these few years been established for that purpose at Wormbridge, near Wellington, in the county of Salop. I understand that at this place considerable quantities of martial pyrites are found intermixed with coal, and that the sulphuric acid obtained from this mineral is used in the decomposition. I have found by experiment, that if muriate of soda can be converted by any means to a *sulphate*, carbonaceous matter alone will furnish the decomposition.

‡ This truth is beautifully illustrated by Dr. Darwin, in the following lines:—

"Organic forms with chymic changes strive,
Live but to die, and die but to revive;
Immortal matter braves the transient storm,
Mounts from the wreck, unchanging, but in form."

CHAPTER VII.

OF ACIDS.

WHAT is an acid ?*

Most of the acids are substances which produce that sensation on the tongue which we call *sour*†; but some substances are classed with the acids which have not this characteristic—though they possess the other properties of acids.

What are the properties of acids ?

Acids change the blue juices of vegetables to red ‡; combine for the most part easily with water; and when united to the alkalies§, or to some of the earths, or metallic oxides‖, form those compounds which are called *salts*.

* The acids differ from each other in their appearance and properties as much as any class of bodies we are acquainted with; it is therefore difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are fixed and inodorous.

† According to Fourcroy, the stronger the attraction of oxygen for the acidifiable radical, the weaker is the taste of the acid: this shows that the corrosive quality of the stronger acids is owing to the *easy* separation of this principle, and its more or less rapid transmission to animal substances.

‡ It is desirable as soon as possible to give the chymical student correct ideas of the properties of the acids and alkalies. To this end, let him be early instructed in the use of chymical tests. If he be accustomed to carry a few test papers in his pocket book, it will be a very rational amusement to try the succulent vegetables which he will meet with in his walks, many of which will be found to contain acids of different kinds. The hope of making an important discovery will furnish an additional zest to this employment. Litmus paper is a good test for acids; and the same paper when reddened by vinegar, and afterwards dried, is a proper test for alkalies. Should litmus not be at hand, common writing paper rubbed over with the rind of the radish will answer every purpose.

§ All those substances which can saturate the alkalies, and cause their properties to disappear, ought to be classed among acids.

‖ The acids have an affinity for the earths, alkalies, and metallic oxides; they are of great use as re-agents.

What is the origin of acids?

Most of the acids owe their origin to the combination of certain substances with oxygen *, which has been called the acidifying principle.

How is it known that oxygen imparts acidity?

It is found that most of the acids contain oxygen, and that they lose their acidity exactly in proportion to the quantity of oxygen which is taken from them†.

Are there any other means of ascertaining this?

Yes: some acids may be decomposed and deprived of their oxygen, and others may be formed by a direct combination of oxygen with their radicals‡.

Do the same radicals always combine with an equal portion of oxygen?

No: some acidifiable radicals combine with different proportions of oxygen, and possess different states of acidity§.

* The substances which are combined with oxygen to form acids are (in all the decomposable acids) *combustible* substances. Indeed several of the acids are the *product* of combustion: witness the sulphuric, the phosphoric, &c.

All the simple combustibles, except hydrogen, are convertible into acids. This is the case also with four of the metals. All bodies, to which the properties of an acid have been ascribed, are either combustibles, supporters of combustion, or products of combustion. Thomson.

It is proper to remark that some of the acids are the productions of art, and are not known to exist in nature. This is the case with the mucous, the suberic, the oxygenized muriatic, &c.

† Many of the acids may be decomposed, and deprived of their oxygen, by combustible bodies. Any combustible body, that has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid. Charcoal, when made red hot, will in this way decompose sulphuric acid. By the disengaged oxygen of the acid the combustible burns; so that, in the language of the French chymists, the acid may be said to be *unburnt* and brought back to the state of a combustible body.

‡ This can be shown by the composition of sulphuric acid, which may be formed with very little trouble in the following manner: Fill a jar with oxygen gas, and invert it upon a plate covered with water. Put a little flour of sulphur into a small iron or tin cup, and place it upon the plate of water under the jar, and then set fire to it with a red hot iron wire. The sulphur will burn with great rapidity, and will be *entirely* converted into sulphuric acid, which may be concentrated by evaporating the superfluous water. In this process the combustion of the sulphur is nothing more than the union of the sulphur with the oxygen gas, which combination forms a substance widely different from either, viz. sulphuric acid gas. The use of the water is to absorb this gas, and render it a fluid, which we call *sulphuric acid.*

If oxygen gas be not at hand, the experiment will answer in common air, if the sulphur be mixed with ⅛ of its weight of nitre.

§ The first portion of oxygen converts bodies into oxides; the second, into that class of acids of which the specific names drawn from their particular bases terminate in *ous*, as the sulphurous acid; the third degree of oxygenizement changes some of these into that division of acids which are distinguished by the termination in *ic*, as the sulphuric acid; and la[illegible]

How do chymists distinguish this difference?

When two acids have the same radical, but contain different quantities of oxygen, they are distinguishable by their termination*. The name of that which contains most oxygen ends in IC, the other in OUS. Thus we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid.

Have acids ever any other degree of acidity?

Chymists have attempted to supersaturate several of the acids with oxygen, but they have succeeded only in one instance†.

Which of the acids has been thus supersaturated with oxygen?

The muriatic acid. In this state it is used in large quantities for bleaching linen. It is called oxygenized muriatic acid ‡.

What substances are capable of being acidified by oxygen?

The mineral, the vegetable, and the animal kingdoms, all furnish bases or radicals, which become acid by their union with oxygen§.

Do all the acids owe their acidity to the presence of oxygen?

The *greater* number of the acids are evidently indebted to oxygen for their acidity, but there are substances that possess acid

can express a fourth degree of oxygenizement by adding the word *oxygenized* to the name of the acid, as oxygenized muriatic acid.

* It is necessary to remark that this mode of distinguishing the doses of oxygen in acids is restricted to that class of acids which is formed by the combination of one simple combustible with oxygen, and does not apply to those acids which are formed with compound radicals and oxygen. Nitrous acid is merely a compound of nitric acid and oxygen.

Thomson.

† The world is indebted to Scheele for the discovery of this combination of oxygen with an acid. He named it the dephlogisticated marine acid; supposing that it was formed by depriving common muriatic acid of its phlogiston.

‡ Though this compound has hitherto been classed among acids by chymists, it does not possess a single property which characterizes that class of bodies. Its taste is not acid, but astringent; it does not convert vegetable blues to red, but destroys them; it combines very sparingly with water, and is incapable of combining with alkalies, earths, or metallic oxides. It ought therefore to be placed among the oxides, rather than the acids.

Thomson.

§ The mineral acids are generally formed with a peculiar base and oxygen; the vegetable acids, with carbon, hydrogen, and oxygen; the animal acids are composed of the same substances united with nitrogen.

Some of the mineral acids are decomposeable by charcoal heated to redness. Some of the vegetable acids are also decomposed, and reduced into water and carbonic acid, by leaving them in an exposed situation to the action of their own principles. Some of them may be converted to *other* acids, by imparting or abstracting a portion of oxygen.

The animal acids are the most liable of all to decomposition. In an elevated temperature the carbon and oxygen unite to form carbonic acid, and the hydrogen and nitrogen produce volatile alkali.

properties which contain no oxygen*. There are also three acids whose composition is unknown †.

How are the acids classed by chymists?

The acids were formerly divided into three classes, viz. the mineral, the vegetable, and the animal acids‡; but the more useful and scientific way of dividing the acids is into two classes only.

How are the acids now divided§?

The undecomposeable acids, and the acids which are formed with two principles, are comprised in the first class; while those acids which are formed with *more* than two principles compose the second class ||.

Can you enumerate the acids of the first class?

The sulphuric and sulphurous acids; the muriatic and oxygenized muriatic acids; the nitric, the carbonic, the phosphoric and phosphorous, the fluoric, the boracic, the arsenic, the tungstic, the molybdic, and the chromic acids.

Enumerate the acids of the second class?

The acetic, the oxalic, the tartaric, the citric, the malic, the lactic, the gallic, the mucous, the benzoic, the succinic, the camphoric, the suberic, the laccic, the prussic, thesebacic, the uric, and the amniotic acids.

What is the SULPHURIC acid?

The sulphuric acid is a combination of sulphur and oxygen¶.

* Sulphuretted hydrogen has all the properties of an acid without oxygen. And it has not yet been proved that prussic acid contains any oxygen.

† Those acids, whose bases are still unknown, are the muriatic, the fluoric, and the boracic.

‡ There can be no objection to retain the former mode of classing the acids, if the *binary* composition of the first, the *ternary* of the second, and the *quaternary* of the third, be always recollected.

§ Those acids of the first class, which are formed with two principles only, are composed of oxygen and some other substance which is called their radical. The acids of the second class are composed chiefly of oxygen, hydrogen, and carbon; though some of them contain nitrogen, as mentioned in a former note.

|| Fourcroy in his last work, entitled "Philosophie Chimique," divides the acids into four classes: 1st, those with known radicals; 2d, unknown ditto; 3d, single ditto; 4th, compound ditto: but I conceive that the above division is better calculated for an elementary treatise.

In the first class we have also the hyperoxygenized muriatic acid; but as this acid has never been exhibited in a separate state, its properties are very little known.

In the second class we have also the mellitic acid; but as this acid has been found only in a very rare mineral, its properties are likewise very little known.

¶ One hundred parts of pure solid sulphuric acid have been said to consist of 72 parts of sulphur and 28 of oxygen; but, according to some late experiments of Mr. Chenevix, it is composed of 61.5 sulphur and 38.5 oxygen.

By comparing the above with Mr. Kirwan's table of the quantity of

It is commonly called oil of vitriol*.

How is the sulphuric acid obtained?

Sulphuric acid is procured by burning sulphur in contact with oxygen; by which process the sulphur combines with the oxygen, and becomes acidified†.

If sulphuric acid is nothing more than sulphur and oxygen, what is it that occasions its fluidity?

Sulphuric acid, at the instant of its formation, is in a gaseous state; therefore the manufacturers find it necessary to condense this gas by means of water. Hence the sulphuric acid of commerce is always in a fluid state‡.

What are the properties§ of sulphuric acid?

acid contained in sulphuric acid of different densities, it appears, that the concentrated sulphuric acid of commerce is composed of

Sulphur	-	49
Oxygen	-	30
Water	-	21
		100

* This acid was formerly drawn from green vitriol (sulphate of iron): hence its name. It has been remarked that the old name *oil* conveys an erroneous idea of the composition of this acid, and that on this account it ought to be entirely dropped. Oil is a compound of carbon and hydrogen; but neither of these substances is contained in sulphuric acid.

† The pupil may be satisfied that sulphuric acid is really produced by the combustion of sulphur, by burning a little sulphur in a glass jar of oxygen gas inverted over water, as directed, page 123. He may immediately see that sulphuric acid has been formed by adding a few drops of a solution of muriate of barytes to the water, from which it will precipitate the barytes.

‡ In the large manufactories for making sulphuric acid (called oil of vitriol works) the sulphur is mixed with ⅛th of its weight of dried nitre, and burnt in very large leaden chambers. The design, in using the nitre, is to give a larger quantity of pure oxygen gas than could be afforded by confined atmospheric air alone. The floor of the chamber is covered with water, that the sulphuric acid gas may be condensed as it is formed. An indefinite quantity of water is poured into the chamber; and when the manufacturer finds that it is become sufficiently acid, this acid water is drawn off and concentrated by boiling. It is then removed to glass retorts, where it receives a greater heat to drive off a further portion of the water. It is considered fit for sale when it is brought to the specific gravity of about 1.845. By keeping it in the retorts for a long time, and in a temperature somewhat lower, it may be concentrated to the specific gravity of 2.000; but it is never brought to this gravity for general sale.

It is possible to render sulphuric acid perfectly transparent without retorting; but such acid is always contaminated with sulphurous acid and nitrous gas. The heat which it acquires in the retorts separates these acids, which go off in combination with the water in a gaseous state.

§ When sulphur is combined with a smaller portion of oxygen it forms a volatile acid of a penetrating smell, called *sulphurous* acid; a larger portion of oxygen gives what we call *sulphuric* acid, which on the contrary is very ponderous and destitute of smell.

The sulphuric is a very ponderous* corrosive acid, destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water†, and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called *sulphates*‡.

What is the SULPHUROUS *acid?*

The sulphurous acid, like the sulphuric, is a combination of sulphur and oxygen; but it contains less oxygen than the latter §.

What are the properties of sulphurous acid?

Sulphurous acid in the gaseous state is invisible like air, but of a strong suffocating smell||. It is readily absorbed by water,

* Sulphuric acid will sometimes freeze, and endanger the bursting of the carboys in which it is contained. Whenever this happens, it is a *proof* that the manufacturer has not sufficiently concentrated it. If it be brought only to the specific gravity of about 1.780, it will freeze much sooner than water. Mr. Kier first pointed this out in the Philosphical Transactions for 1787.

† Sulphuric acid has a great affinity to water; it combines so intimately with it that the water becomes very much condensed, and gives out a large portion of caloric. Four pounds of this acid mixed with one pound of water raised the thermometer to 300°.

The sulphuric acid of commerce is never perfectly pure—it always contains a portion of sulphate of lead and sulphate of potash. The former comes from a partial dissolution of the lead of the chamber in which it is made, and the latter from the nitre which is always used in the process.

Concentrated sulphuric acid does not act upon lead unless by the assistance of heat. It acts slowly upon iron; but if diluted it dissolves iron with great rapidity. Excepting iron and zinc, most of the metals are insoluble in diluted sulphuric acid.

‡ Sulphuric acid is a good test for barytes. Pour a little into a solution of muriate of barytes, and an abundant precipitate of sulphate of barytes will be produced. It is also a good test for lead.

I know only of *one* case in which this acid will not discover the presence of barytes, and that is when sulphuric acid is contaminated with this earth. Mr. Hume has shown, in the Phil. Mag. vol. xiv. 357, that sulphate of barytes is completely soluble in sulphuric acid.

§ Sulphurous acid gas is produced by the *slow* combustion of sulphur. If this gas be received in water, the gas combines with it, and sulphurous acid will be the result. Water at 40° absorbs one third of its weight of sulphurous acid gas.

Sulphurous acid gas may be procured by the following process: put into a glass retort two parts of sulphuric acid and one part of mercury, and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing in a mercurial trough. Dr. Thomson. In this process the mercury combines with part of the oxygen of the sulphuric acid; and the sulphuric acid, having lost a certain portion of its oxygen, is converted into *sulphurous* acid.

Any combustible substance will in part decompose sulphuric acid, by combining with a portion of its oxygen, and sulphurous gas will be evolved.

|| This gas is very abundant in the environs of volcanoes. It was the vapour of sulphurous acid which suffocated Pliny the naturalist, in that

and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms salts called *sulphites*.

What is the MURIATIC acid?

The muriatic is a peculiar acid obtained from sea-salt*. It has been supposed that it acquires its acid properties from oxygen; but however this be, the radical or base of this acid is still unknown†.

What method is made use of to collect and preserve the muriatic acid?

Muriatic acid is drawn from sea-salt by distillation, and col-

eruption of Vesuvius by which Herculaneum was swallowed up in the year of Christ 79. Anxious to observe the effects of the eruption, he staid in the house of a friend too long, and paid for his temerity with his life.

Sulphurous acid gas is composed of 68 parts sulphur and 32 parts oxygen. Its weight is more than double that of atmospheric air.

This gas has been prescribed by physicians in affections of the lungs, and in those diseases which are owing to an excess of oxygen in the system. The liquid acid is administered in asthmas.

Sulphurous acid gas is used by manufacturers in bleaching silk. A slow combustion of sulphur is promoted in a close chamber, and the goods are exposed to the gas as it is produced. The same process is employed to alter the hue of different colours. Thus, silks which are dyed by archil of a dark lilac are brought to a beautiful flesh-colour by exposure to the fumes of this gas. Flesh-coloured silk stockings are coloured in this way.

Sulphurous acid possesses very slight acid properties. Instead of changing vegetable blues to a red, it invariably renders them white. If a red rose be held in the fumes of a brimstone match, the colour will soon change, and at length the rose will become white. By the same process, fruit stains or iron-moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water.

* Glauber was the first who procured this acid from sea-salt by means of sulphuric acid; but the directions given by him in the first part of his Treatise on Philosophical Furnaces, 1651, quarto, page 9, are truly ludicrous and absurd.

This acid was known only in a liquid state till Dr. Priestley taught us how to procure it perfectly pure in a gaseous form.

Mr. Chenevix has proposed a new nomenclature for this acid and its combinations with oxygen:—he proposes to say

Muriatic radical	instead of	Muriatic acid,
Muriatous acid		Oxygenized muriatic acid,
Muriatic acid		Hyperoxygenized muriatic acid.

Phil. Trans. vol. xcii. 126.

† Dr. Girtanner supposed the base of this acid to be hydrogen; but no one has taken so much pains to ascertain its nature as Mr. Henry. See his paper on this subject in the Phil. Trans. vol. xc. 188.

Berthollet has published a memoir, in which he endeavours to prove that this acid is composed of nitrogen, hydrogen and oxygen. He says that if iron filings moistened with water be exposed for some days to the air, they will exhibit evident traces of the presence of muriatic acid.

Dr. Lambe, an ingenious physician, late of Warwick but now of this

lected in appropriate receivers, where it is condensed by means of water, for which it has powerful affinity*.

What are the properties of muriatic acids?

This acid in the gaseous† state is invisible like air; has a pungent suffocating smell; and is not decomposeable by art ‡. With water it forms liquid muriatic acid, which preserves the smell of the gas, and gives out white fumes when exposed to the air. This acid is much employed in the arts§, and in chymical la-

city, is of opinion that sulphuretted hydrogen is the base of this acid. See Manchester Mem. vol. v.

It was lately announced that muriatic acid has been procured from the decomposition of water by the Galvanic pile; but it is supposed that the reporters were deceived in the result of their experiments, and that the acid proceeded from the perspirable matter which exuded from the hands of the operators; as it is well known that muriate of soda does actually exude from the skin.

* This acid is disengaged from muriate of soda in the state of gas, by a process similar to that for drawing the nitric acid; it preserves its gaseous state even in the coldest temperature, unless it come in contact with water. It is combined with so large a portion of caloric, that if it be thrown upon ice it melts it in an instant. It is nearly double the spec. grav. of atmospheric air.

Liquid muriatic acid, or water saturated with this gas, is about the spec. grav. 1.196. The muriatic acid of commerce varies from about 1.120 to about 1.164.

Bergman says, that 100 parts of muriate of soda contain 52 of muriatic acid and 6 of water. That this statement is erroneous, any chymist may satisfy himself of by experiment. I have frequently tried it in the large way, and could never procure more than 44 parts of acid and water from 100 parts of dried muriate of soda.

† Muriatic acid gas may be obtained for chymical experiments, by pouring one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collecting the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. This gas may also be procured by heating the muriatic acid of commerce in a glass retort, and collecting the gas over mercury as usual.

Retorts are not always of glass; they are sometimes made of stone-ware, or iron. They are of various sizes, from eight ounces to eight or nine gallons. The best stone-ware retorts are made by Messrs. Wedgwood and Byerley. Glass ones may be had at the large glass warehouses in London, and elsewhere.

‡ Sulphuric, phosphoric, nitric, and other acids may be decomposed by charcoal: muriatic acid is unalterable by any of the combustibles with which we are acquainted.

Muriatic acid will decompose the carbonates, the phosphates, and most other salts; but it is itself generally expelled in its turn by the sulphuric acid.

§ Muriatic acid is the best test for silver. If a single drop be poured into a solution of nitrate of silver, a copious precipitate will immediately follow owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

boratories. With various bases it forms salts, called *muriates**.

What is he OXYGENIZED MURIATIC *acid?*

The oxygenized muriatic acid is formed with muriatic acid and oxygen †. It is known in the gaseous state, and in combination with water: in the latter it is commonly used in the arts.

What are the properties of oxygenized muriatic acid?

The oxygenized muriatic acid gas is so suffocating, that it can-

* Muriatic acid attacks oxide of iron with more rapidity than the sulphuric. It dissolves tin and lead. At a boiling heat it oxidizes copper.

Muriatic acid removes the stains of common ink, but it does not affect printers-ink. It is therefore recommended for cleaning old books and prints. Half an ounce of red-lead being added to three ounces of common muriatic acid, will render it fit for this purpose. Parkinson. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia and prussiate of potash will revive the writing, and discover the artifice. Very old writing may be revived in this way. If indigo and oxide of manganese be added to common ink, it will prevent its being effaced by oxygenized muriatic acid.

The citric acid is proper for removing ink stains from linen, but they are best removed when recent. If they remain long on the cloth, the iron of the ink acquires that degree of oxidizement which renders it insoluble in acids. When ink stains are thus become what are called *iron-moulds*, they may be removed by oxalic acid, or by first washing them with a solution of sulphuret of potash to absorb the oxygen, and then applying the acid of lemon as usual.

† Oxygenized muriatic acid is composed of 84 parts muriatic acid and 16 parts oxygen. The hyperoxygenized acid is formed with 35 parts acid and 65 parts oxygen. Mr. Chenevix, Phil. Trans. 1802.

Muriatic acid has a great affinity for oxygen. When fully oxygenized it seems to have lost all its acid properties, as it becomes incapable even of expelling carbonic acid from alkalies or lime. If oxygenized muriatic acid be exposed to light, the light combines with part of the oxygen, and the oxygenized muriatic acid is then converted into common muriatic acid.

The effect of giving a dose of oxygen to this acid is quite the reverse of the acid of sulphur, it being rendered more volatile thereby, and of a very penetrating smell; whereas the addition of oxygen to sulphurous acid gives it more density, and renders it quite inodorous. The combination of oxygen gives a greenish yellow colour to this gas. Common muriatic acid gas is invisible.

This gas may be obtained for chymical experiments by the following method: Put into a retort one part of black oxide of manganese in powder; and having poured three or four parts of strong muriatic acid upon it, connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance.

The variolous poison will not take effect when mixed with oxygenized muriatic acid. Fourcroy hence imagines that this acid would prevent the effects of hydrophobia. See his paper on oxygen in Annales de Chimie.

Accounts have been received from Spain, that in the midst of the dreadful contagion which reigned in that country, the inhabitants of those houses where fumigations of oxygenized muriatic acid were used, had no attacks of the sickness, and enjoyed the best health.

not be breathed without great injury*; yet it will support combustion. This acid discharges vegetable colours†; it oxidizes all the metals‡, and is the only acid that will dissolve gold and platina§. With various bases it forms salts, called hyperoxygenized muriates.

What is NITRIC *acid?*

Nitric acid is one of the constituent parts of nitre, or salt-petre‖. It is a composition of oxygen and nitrogen¶, in the proportion

* The death of the ingenious and indefatigable Pelletier was occasioned by his attempting to respire this gas. A consumption was the consequence, which in a short time proved fatal. Dr. Thomson, vol. ii. 82.

† Other acids impart a redness to vegetable colours; this makes them white, by imparting its oxygen; and is itself changed thereby to common muriatic acid.

The great use of oxygenized muriatic acid is in bleaching. The colouring principles of vegetables have a great affinity for oxygen; they therefore absorb oxygen from this acid, and after this absorption are soluble in alkalies. On this principle the modern practice of bleaching is founded. The manufacturer might derive considerable advantage from the perusal of Mr. Rupp's paper on the use of this acid, in the fifth volume of the Memoirs of the Manchester Society. See also Charmes on Bleaching, 8vo.: Robinsons, 1799. C. Potel of the Academy of Dijon has shown that the fears of those who suppose this process *burns* the cloth are groundless; and that, if the operation be performed by a careful workman, it improves texture of the cloth instead of injuring it. Phil. Mag. vol. xiv.

‡ It oxidizes all metals without the assistance of heat. Metals beaten into thin leaves, or reduced to powder, inflame when thrown into a vessel filled with this gas, and present a kind of shower of fire. The following is a pleasing and instructive example:

Prepare a jar of oxygenized muriatic gas, and suspend in it a piece of Dutch metal, or copper-foil: it will inflame immediately, and the combustion will continue, affording a striking spectacle, till the whole is consumed. As the metal combines with the oxygen, the acid dissolves it, and acquires thereby a green colour. This will subside in the jar, and form a substance exactly similar to the native muriate of copper brought from Peru. This experiment affords an example of the oxidizement of metals, and of the affinity which acids have for metallic oxides.

§ Nitro-muriatic acid will dissolve gold; but its solution in this mixed acid is owing to the muriatic acid having acquired oxygen from the nitric, sufficient to convert it to oxygenized muriatic acid.

Mr. Humboldt has found that seeds which do not commonly germinate in our climates, or in our hot-houses, and which of course we cannot raise for our gardens, or hope to naturalize in our fields, become capable of germinating when immersed for some days in a weak oxygenized muriatic acid. This interesting discovery has already been turned to advantage in several botanic gardens.

‖ This acid was known to Raymond Lully in the thirteenth century; but it was Mr. Cavendish who discovered its component parts, in the year 1785. See his paper in the Philosophical Transactions for that year.

¶ If a proper mixture of these gases be made in a glass tube, and a number of electric explosions passed through this mixture, the gases will un[ite] and *nitric acid* will be the product. Being formed of the same subs[tances] with atmospheric air, we have no difficulty in accounting for the na[tural] production of this acid.

of about 25 parts by weight of the latter, to about 75 of the former*.

How is nitric acid obtained?

Nitric acid is obtained by distilling two parts of nitre and one part of sulphuric acid in a glass retort, and collecting the gas in proper receivers†. This acid, which at first contains nitrous gas and other impurities, is rendered transparent and colourless by the application of heat in a subsequent process.

What are the properties of nitric acid?

Nitric acid is clear and colourless, like water; its smell is acrid; its taste exceedingly acid; and its action on animal substances very corrosive. It has a property of permanently staining the skin yellow. It has a great affinity for water‡; is capable of oxydizing most of the metals §, and with various bases forms salts called *nitrates*.

What constitutes the acid of commerce, called NITROUS *acid?*

* These proportions were ascertained by Mr. Davy.

It is curious that the substances which compose atmospheric air, so necessary to our existence, should, in different proportions, produce also one of the most corrosive acids.

$$\left.\begin{array}{rl} 22 & \text{parts of oxygen, with} \\ 78 & \text{— of nitrogen,} \end{array}\right\} \text{form atmospheric air.}$$

$$\begin{array}{r} \hline 100 \\ \hline \end{array}$$

$$\left.\begin{array}{rl} 75 & \text{parts of oxygen, with} \\ 25 & \text{— of nitrogen,} \end{array}\right\} \text{form aqua-fortis.}$$

$$\begin{array}{r} \hline 100 \\ \hline \end{array}$$

Should the evidence already adduced be not sufficient to convince us of the *infinite* comprehension of the Divine mind, such facts as these are surely irresistible.

None but Deity could have had a conception how such *different* substances could have been produced from the *same* principles. But Almighty Power performs with infinite ease, whatever Infinite Wisdom seems fit to appoint.

† The manufactories of this acid are commonly called aqua-fortis works. The acid is drawn of different strengths, from 1.125 to 1.460, according to the purposes for which it is designed. It is used in dyeing, in refining gold, in medicine, &c. &c. It is very prone to combination, and very easily decomposed.

‡ It appears very singular that nitrate of barytes, which is so soluble in water, is perfectly *insoluble* in nitric acid. This, I believe, was first n[illegible] by Mr. Hume.

§ If nitric acid be poured on iron filings, the acid will in part be de[illegible] sed [illegible] oxygen will render the metal soluble, and the nitrous gas [illegible] [illegible]t in copious red fumes.

Nitrous acid is nothing more than nitric acid* impregnated with nitrous gas†.

What are the properties of nitrous acid?

Nitrous acid is very similar to *nitric* acid in its properties‡; but its colour varies according to the proportions of nitrous gas which it has absorbed, and the water which it contains§.

What is CARBONIC acid?

Carbonic acid || is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being found in chalk, lime-stone¶, magnesia, &c.

What are the properties of carbonic acid?

Carbonic is invisible when in the state of gas, but is unfit for combustion**, or respiration††. By pressure, water may be made

* It was formerly supposed that this acid differs from *nitric* acid in this—that it contains less oxygen: hence it was called, agreeably to the new nomenclature, *nitrous* acid; but it is now found that this is not the case. See Davy's Researches.

† Dr. Priestley having separated nitrous gas from nitric acid, by means of iron, received the gas under an inverted vessel filled with water, and found it a transparent *colourless* gas, resembling air; whence it appears that it is red, or coloured, only when combined with atmospheric air. To Dr. Priestley we owe the discovery, that nitrous gas is converted into nitrous acid by its union with oxygen and water. See Priestley on Air. Fourcroy, part iii. ch. 4.

On the principle that oxygen gas is necessary to convert nitrous gas to nitrous acid, Dr. Priestley invented his eudiometer, to discover the degree of purity of atmospheric air.

‡ Nitrous acid is generally used for purposes of trade or experiment. The *nitric* acid is principally employed in medicine.

Two parts of this, and one of muriatic acid, form aqua-regia, or nitro-muriatic acid, the true solvent of gold. It is curious that this acid has less specific gravity than either of the acids from which it is composed.

§ The changes which take place on the addition of water to strong nitrous acid exhibit very curious phænomena. Different portions change its colour to a blue, a green, a yellow, &c. while the vapours which rise from it preserve their original flame-coloured red.

|| To Dr. Black we owe the discovery of carbonic acid gas. Mr. Keir was the first who suspected it to be an acid; and Dr. Priestley afterwards announced that this gas entered into the composition of atmospheric air.

¶ Carbonic acid is composed of 18 parts carbon and 82 oxygen; which has been ascertained by analysis as well as synthesis. Mr. Tennant was the first who decomposed this acid. This he effected by the following means: He burnt phosphorus in a close vessel, in which was a portion of carbonate of soda. The phosphorus absorbed the oxygen from the carbonic acid, and the carbon was separated in the form of a black powder.

** If this gas be poured from a wide-mouthed jar upon a burning candle, it extinguishes it like water. Its superior gravity to atmospheric air, and [illegible]fitness for supporting combustion, may be better shown by pouring a [illegible] glass full of this gas into another tall glass, containing a short taper [illegible] within it.

†† Fourcroy says, this gas, when mixed in a small proportion with atmospheric air, may be inhaled without danger, by patients who have sym-

to absorb three times its bulk of this gas; by which it acquires an agreeable acidulous taste*. Carbonic acid enters into combination with the alkalies, with some earths, and some metallic oxides; and forms with them those salts called *carbonates*†.

What is PHOSPHORIC *acid?*

The phosphoric acid is a compound of oxygen and a peculiar substance called phosphorus‡.

How is phosphoric acid procured?

Formerly phosphoric was procured only by burning the phosphorus obtained from urine in oxygen gas; but now it is known that phosphoric acid, *ready* formed, is a component part of animal bones§; it is procured from them at a much cheaper rate.

What are the properties of phosphoric acid?

toms of ulceration, or inflammation of the lungs; and that it will either cure these complaints, or retard their destructive effects.

* Carbonic acid gas is found in abundance in many natural waters. This is the case with the waters of Seltzer, Pyrmont, and Spa, in Germany. Those of Seltzer are very *highly* carbonated. They are so pleasant and salutary, that various imitations of them, made in this country, are sold under the names of single and double soda water. They are manufactured by Mr. Paul of London, and Mr. Henry of Manchester, equal in every respect to the natural waters imported from the continent.

† The earthy carbonates are insoluble in water. Hence, breathing into a phial of lime-water renders it turbid; and thus lime-water is a good test for the presence of carbonic acid.

‡ During a great part of the last century, this acid was supposed to be a modification of the muriatic acid. This error originated with Stahl. In 1743, Margraff distinguished it from all other acids; and in 1772, Scheele discovered that it was a component part of animal bones.

§ When animal bones are divested of their oil and jelly, the earth which remains is chiefly lime, united with the phosphoric acid. It is worthy of notice, that phosphate of lime is found in abundance also in milk. This seems to indicate, as Fourcroy beautifully remarks, "that Nature thought fit to place in the first nourishment of animals a quantity of osseous matter, with a view to the necessary celerity of the formation and growth of the bones in the earliest stage of their lives." This fact is probably unknown to some who study natural history, and is one of the numerous instances of the beneficence of the Creator, exemplified by the science of Chymistry. The more we know of the minutiæ of matter, and of the laws by which it is governed, the greater occasion shall we have to admire the excellence of contrivance and the benevolence of intention of the Omnipotent Artificer. Let the advocates for chance consider the aforesaid fact, and say, if they can, that phosphate of lime is found in animal milk, in consequence of *fatality*, and that it occurs by *accident* where it performs so important an office in the animal œconomy.

It is a remarkable fact, that the nearer the female approaches to the period of parturition the more is the milk charged with this calcareous phosphate; and that it is not till the digestive organs of the infant are sufficiently strengthened to answer the purposes and the work of animalization, that this earthy salt disappears from the milk of the mother. See Nicholson's Journal, 4to. vol. i. 205.

Phosphoric acid deprived of water, is solid, and transparent*; when liquid, it has a thick oily appearance, and is of considerable gravity, and very acid to the taste†. It forms a variety of salts, called *phosphates*, by its union with earthy, alkaline, and metallic bases.

What is the PHOSPHOROUS *acid?*

This acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus‡; for when phosphorus is heated it burns *rapidly*, and the product is *phosphoric* acid.

What are the properties of phosphorous acid?

Phosphorous acid is a dense, viscid liquid, with an acid taste, which emits the smell of garlic when heated. It may be decomposed by charcoal, like the phosphoric acid, but it cannot like it be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites*.

What is FLUORIC *acid?*

The fluoric, is an acid of a peculiar nature§, found in the fluor

* Pure phosphoric acid obtained, without the addition of water, by burning phosphorus in oxygen gas, has the form of white, snowy, light flocks, of a very strong acid taste. By exposure to the air it attracts humidity, and becomes a *fluid* acid. Forty ounces of phosphorus will produce more than 100 ounces of dry acid.

† Phosphoric acid may be concentrated till it is of greater specific gravity than sulphuric acid; but though the taste is very acrid, it does not possess a causticity sufficient to burn organic substances.

If phosphoric acid be exposed to heat it gradually becomes thick and glutinous; and if the heat be continued it acquires more consistence, and at last melts into a solid transparent glass. This phosphoric glass must be preserved from the action of the atmosphere, or it will be gradually dissolved again into liquid phosphoric acid. If the phosphoric acid has been fused in an *earthen* crucible, it will not be deliquescent nor soluble in water.

This acid has been prescribed by some physicians as an antisceptic, cooling, and solvent medicine, and as an external application in osseous tumours.

‡ Phosphorous acid is generally procured by exposing sticks of phosphorus to the action of atmospheric air, in a glass funnel, and receiving the acid, as it forms, in a bottle placed underneath. It is necessary previously to put a small quantity of distilled water into the bottle, and to stop the neck of the bottle *partially*, so as to prevent the sticks of phosphorus from falling within it. The pieces of phosphorus should be laid upon the funnel, so as not to touch each other.

§ This acid is obtained by pouring sulphuric acid upon the powdered spar in a leaden retort, and applying a gentle heat. The sulphuric acid expels the fluoric, and unites with the lime in its stead.

Fluor spar requires its own weight of concentrated sulphuric acid to disengage the fluoric acid gas, which must be received in water like the muriatic. To preserve the liquid acid, it must be kept in bottles lined on the inside with wax dissolved in oil, or in vessels of lead or platina.

spar*, which is a natural production, composed of this acid and lime.

What are the properties † of fluoric acid?

In the state of gas it is invisible like air. Water rapidly absorbs it, and forms *liquid* fluoric acid. It has an acid taste, and the peculiar property of dissolving silex‡. Its radical is not known.

What is the use of fluoric acid?

Fluoric acid has not been used except for corroding glass§; for which purpose it was employed in the 17th century‖.

What is BORACIC acid?

The boracic acid is a peculiar acid separated from a sub-

* Fluor spar is found in many parts of Europe, particularly in Derbyshire. Some of it is so extremely beautiful that it is often employed in the manufacture of ornamental vases, &c. &c.

† This acid has somewhat of the smell of muriatic acid, but is much more corrosive. It acts so powerfully on silex that it is impossible to use glass vessels for its distillation where any large quantity of the acid is required. A glass retort would be destroyed before a pound of the gas could be obtained. It combines with the siliceous earth of the glass, and carries it over with it in distillation.

Its action on glass may be shown by strewing a little powdered fluor spar on the surface of a pane of glass, and pouring a little sulphuric acid upon it. The sulphuric acid will disengage the fluoric acid from the spar, which will act upon the glass as it becomes disengaged.

‡ If a small animal or reptile be exposed to the vapour of this acid drawn in glass, the moisture it contains will dissolve the acid, and the silex will be precipitated upon it, so as to give it the appearance of a real petrifaction, covered with a hard and durable coating.

§ I am informed that it is become a fashionable employment for young ladies to etch landscapes and other drawings on glass by means of this acid. They cover the surface of the glass with wax, and trace the drawing by cutting out the wax with proper instruments. The piece is then put into a leaden receiver, and the gas disengaged from the fluor spar by means of an Argand's lamp thrown in upon it. In this way drawings of great beauty are made, as imperishable as the glass itself. A complete apparatus may be had of Messrs. Knights, Foster-lane, Cheapside, London, for about four guineas; it is so contrived, that a lady may operate with it in a sitting-room with great safety; and by varying the process the full effect of *light and shade* may be given to the drawings: for, if *liquid* fluoric acid be used, the lines will be transparent; whereas, if it be applied in the state of gas, they will appear dark and opake.

In France, barometers, thermometers, and other glass instruments, are graduated by means of this acid. But if ths acid contain any silex, it will not act on glass. It might be usefully employed for engraving labels on glass bottles, designed to hold the corrosive acids.

‖ Henry Swanhard, an artist of Nuremberg, having discovered the corrosive nature of this acid by observing its effect upon his spectacles, on which sc[illegible] accidentally fallen, applied it to the purposes of engraving on glas[illegible] is 1670. See Mr. Nicholson's Journal, 4to, vol. iv. 1.

stance called Borax *. Its component parts are unknown †.

What are the properties of boracic acid?

Boracic acid is in the form of thin scales‡, slightly acid§, and unalterable in the air. It forms a variety of salts called *borates*, when combined with the alkalies, some earths, and some of the metallic oxides. The characteristic property of this acid is, that it imparts a green colour to burning bodies‖.

What is ARSENIC *acid?*

Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass; very soluble in hot water¶; of an acid taste, and poisonous. With different bases it forms salts called *arseniates*.

What is the TUNGSTIC *acid?*

The tungstic acid is a tasteless yellow powder, composed of oxygen and tungsten**. It is insoluble in water, but forms salts called tungstates, by its union with alkalies and earths††.

What is MOLYBDIC *acid?*

* The boracic acid was discovered by Homberg in 1702. It may easily be procured by dissolving refined borax in hot water, and adding sulphuric acid till the solution has a slight acid taste. This is then to be left to cool and and crystallize. Dr. Thomson, vol. ii. 51.

† See an account of Crell's experiments for the decomposition of this acid in Annales de Chimie, tome xxxv. 202. He has announced that carbon is one of its component principles.

‡ This acid, when it is well crystallized, is in the form of small shining flaky crystals. If exposed to a strong heat, it becomes fused and forms a solid white glass, which is sometimes employed in the composition of artificial precious stones.

§ The taste of this acid is bitterish, with a slight degree of acidity. It is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all the stones into solution. See Mr. Davy's late paper on this subject in the Philos. Trans.

‖ When burnt with alcohol it communicates a green colour to the flame, which becomes more and more green as the alcohol burns away. If a paper be dipped in alcohol and then sprinkled with this acid, it will burn with a green flame.

¶ This acid is not affected by exposure to the air. It is composed of 65 parts of arsenic and 35 oxygen. It is made by giving an extra dose of oxygen to the common white oxide of arsenic, which of itself possesses several of the properties of an acid, and has by Fourcroy been called *arsenious* acid.

** This acid is found native in wolfram and other minerals. It may be obtained from wolfram by boiling three parts of muriatic acid on one part of the mineral. The acid is to be decanted off in about half an hour, and allowed to settle: the powder which precipitates is to be dissolved in ammonia; the solution evaporated to dryness, and the dry mass kept for some time in a red heat. It is then yellow *oxide*, or the *tungstic acid*, in a state of purity. Dr. Thomson, vol. i. 250, 2d edit. This acid becomes *blue* by exposure to the light.

†† Tungstic acid unites with the alkalies to saturation.

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Molybdic acid is a white powder, composed of molybdenum and oxygen*. It requires a large quantity of water to dissolve it†; but it combines with several radicals, and forms with them salts called *molybdates*‡.

What is CHROMIC acid?

Chromic acid is an orange-coloured powder, composed of cromium and oxygen. It has an acrid metallic taste, soluble in water, and crystallizable. It assumes a variety of beautiful colours when mixed with different saline solutions; it also forms various salts, called *chromates*, with the earths and alkalies§.

What is the ACETOUS acid?

Acetous acid, or vinegar, is prepared‖ from saccharine liquors¶, which have undergone the vinous fermentation**.

What are the properties of acetous acid?

Acetous acid is a pleasant yellow liquor, well known. When distilled it is as colourless as water, and of an agreeable odour. In

* This acid was discovered by Scheele in 1778. It is procured from the sulphuret of molybdenum by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified; which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and leaves the molybdic in a state of purity. Dr. Thomson, vol. ii. 103.

† It requires 960 parts of boiling water to dissolve it. The solution is a pale yellow.

‡ This acid dissolves several metals, and assumes a *blue* colour in proportion as it abandons to them a part of its oxygen. Hume, Phil. Mag.

§ The chronic acid was discovered by Vauquelin. It is procured from the red lead ore of Siberia. He obtained it by boiling 100 parts of this mineral with 300 of carbonate of potash and 4000 water, and separating the lead and the alkali by weak nitric acid. For an account of the different colours which this acid assumes, see Dr. Thomson, vol. ii. 105.

‖ In making vinegar the casks should be only half filled: by this method a large surface of the liquor will be exposed to the atmosphere, from whence the oxygen is to be derived to acidify it.

¶ All kinds of wine, and all sorts of malt or saccharine fermented liquors, are capable of yielding this acid. The *smaller* the quantity of the wine the sooner will it be converted to vinegar, provided there be a free access of atmospheric air. Ample directions for making vinegar will be found in Fourcroy's System of Chymistry, vol. viii. 250: but I believe the best treatise on this subject is by Citizen Parmentier, published in one of the volumes of the Annales de Chimie.

It is found that wine which contains most mucilage soonest becomes acid. On this account isinglass ought not to be added to wines, to fine them, till the moment of bottling them.

** It was formerly imagined that acetous acid could be prepared only from vinous liquors; but it is not an indispensable condition that it shall have been preceded by the vinous fermentation. This acid may be drawn from several kinds of wood by the destructive distillation. Mr. Andrew Patter
very large manufacture of this acid near Manchester, where the wood
in large iron cylinders about 8 feet long and 3 feet diameter. The
iefly used in making acetate of iron for the calico-printers.

both states it is known in commerce by the name of vinegar*.

What is the acid which has been usually called ACETIC *acid?*

Acetic acid is obtained from acetate of copper, acetate of soda, or acetate of potash. It was formerly thought to be a distinct acid; but it has lately been demonstrated by experiment to be merely *acetous* acid in a concentrated state†.

What are the properties of acetous acid in this state of concentration?

Acetic acid thus prepared is pungent, acrid, and volatile‡, and corrodes ainnal substances. With various radicals it forms salts called *acetates*§.

What is OXALIC *acid?*

The oxalic is a peculiar acid found in the juice of sorrel, in combination with potash‖. The radical of this acid exists also in sugar and other matters, which require only the addition of oxygen to form true oxalic acid¶. It crystallizes in four-sided prisms, has a very acid taste, and is soluble in water. It is composed of ovygen, hydrogen, and carbon.

* There is so little difference between the volatility of vinegar and water that it cannot be concentrated by boiling; but if it be mixed with charcoal dust, the charcoal will enable it to resist a strong heat, by which means the water may be thrown off by a boiling heat; and then the pure concentrated acetous acid may be drawn over in a proper apparatus by a stronger heat. We are indebted to Mr. Lowitz for this discovery.

† Darracq has shown that acetous and acetic acid both produced the same combinations, and gave the same products in their decompositions. He brought acetous to the state of acetic acid by distilling it several times over muriate of lime, and then was able to form ether with it as with the acetic acid obtained from acetate of copper. Annales de Chimie, tome xxvii.

‡ This acid evaporates entirely when exposed to the air; and when heated with free access of atmospheric air, it takes fire so readily that one is tempted to suspect the presence of ether in it.

§ Acetic acid may be advantageously employed to separate manganese from iron. When a mixture of these two metals is dissolved in this acid, and the solution evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese, and the oxide of iron will be left on the filter. Two or three evaporations and solutions are sufficient to deprive acetate of manganese of the whole of its iron.

‖ Sal-acetosellæ, or the salt of sorrel of commerce, has usually been imported from Switzerland and the neighbouring countries, where it is prepared in large quantities from the juice of sorrel. According to Savary, one hundred pounds of the plant afford five ounces of the crystallized salt.

Deyeux has found a considerable quantity of this acid in chick peas. It was discovered by its burning the shoes of some persons who walked over a field of this pea. There is reason to believe that, by a chymical examination of other plants from which acid humours spontaneously flow, this acid will be found to exist in greater abundance than has been suspected. Fourcroy.

¶ The oxalic radical appears to exist more abundantly in insipid matters than in sugar. Berthollet has obtained from wool more than half its weight of oxalic acid. Fourcroy.

What are the uses of oxalic acid?

The oxalic acid is of great use to chymists to detect the presence of lime in solution*. It is also become an article of great consumption with the calico-printers, both in a state of purity and in combination with potash†. In combination with earths, alkalies, and metallic oxides, it forms salts called *oxatates*‡.

What is the TARTARIC acid?

Tartaric acid is a peculiar acid found in the cream of tartar of commerce§. It is capable of crystallization, and easily soluble in water. Salts formed with this acid are called *tartrates*. It is used by calico-printers to discharge false prints‖.

What is CITRIC acid?

Citric acid is found in the juice of lemons and several other fruits¶. It crystallizes in beautiful rhomboidal prisms; is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, for medicine**, and

* The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth. Thus, if a few drops of the solution of oxalic acid be dropped into a neutral solution of muriate of lime, an abundant precipitate of insoluble oxalate of lime will appear. I say a *neutral* solution of muriate of lime, for if there be any excess of muriatic acid in the solution the lime will be redissolved.

It is probably owing to the affinity which this acid has for lime that sugar is injurious to the teeth.

† The calico printers have attempted to use the acidulous oxalate of potash instead of the citric acid; but it is so little soluble in water, that they find a difficulty in making their solutions of a sufficient strength. The pure oxalic acid answers better for many purposes, as it is cheaper, and water will dissolve half its weight of it.

‡ The oxalic acidule attacks iron, zinc, tin, antimony, and lead. It dissolves also the oxides of all the other metals, and forms with them triple salts. It is employed to take out ink spots from linen, &c. which it does by virtue of its attraction for iron. Fourcroy.

§ Tartar is procured from vessels in which wine has been kept. The tartaric acid appears to be a necessary substance in all wine; for it seems from some late experiments that *must* will not ferment if all the tartaric acid be taken from it. Dr. Thomson, vol. iv. 458.

‖ Scheele was the first chymist who obtained this acid in a separate state.

By varying the proportion of oxygen we may obtain at pleasure acetous, tartaric, malic, or oxalic acid. The base of each of these acids being carbon and hydrogen, different proportions of oxygen produce the different acids as above.

¶ Scheele was the first person who obtained this acid from the juice of lemons in a state of purity. When crystallized it suffers no alteration from exposure to the air, though it is said to change after some time when dissolved in water.

** Within these few years an important use has been made of this acid in medicine. It is said that the largest dose of opium may be checked in its narcotic effects, if a proper quantity of citric acid be taken with it. And with this adjunct it induces cheerfulness instead of stupefaction, succeeded by ge[illegible]freshing sleep. Dr. Willich on Diet.

by calico-printers*. Salts formed with it are called *citrates.*

What is MALIC *acid?*

Malic is obtained from the juice of apples, in which it exists ready formed†. It is a very acid, reddish-coloured liquid, composed of oxygen, hydrogen and carbon, like the other vegetable acids‡. It is incapable of crystallization, and has not yet been brought into any use except as a chymical test§. Its salts are called *malates.*

What is LACTIC *acid?*

Lactic acid is prepared from whey. It is incapable of crystallization, and has not been brought into use. Salts formed with it are called *lactates*‖?

What is GALLIC¶ *acid?*

Gallic acid is found in the galls of commerce, and in most astringent vegetable substances**. It is obtained in thin transparent plates, and in minute needle-shaped crystals, of an acid austere taste††. Its salts are called *gallates.* It has the property of

* This elegant acid is very useful to our manufacturers on account of its solubility. One ounce of cold water will dissolve 1¼ oz. of it, and boiling water will dissolve double its weight. The proper method of procuring it in crystals may be seen detailed in Ann. de Chimie, tom xxii. See also Dr. Thomson. vol. ii. 146.

† This acid is found not only in apples, but in strawberries and other summer fruits. It was discovered by Scheele in the year 1785. For the best method of procuring it, consult Dr. Thomson, vol. ii. 160.

‡ Malic acid by the addition of nitric acid is converted to the oxalic acid.

§ Malic acid is of use in the analysis of earths for separating *alumine* from *magnesia*, as it forms with the former an insoluble salt, and precipitates.

‖ Fourcroy and Vauquelin have asserted, that the acid which is developed in milk is nothing but acetic acid modified by some animal substances and some salts which it holds in solution. Phil. Mag. vol. xxii. 176.

¶ Gallic acid is soluble in 10 parts of cold water, and in 3 of boiling water. It is not altered by exposure to the air, but is decomposeable by heat.

** Gallic acid exist in galls, in oak bark, and other vegetables, independent of the astringent principle. It is lately found that the property of giving a black colour to the solutions of iron is owing to this acid and not to the astringent principle as was formerly supposed. A short process for procuring gallic acid in a separate state may be seen in Crell's Chymical Annals for the year 1787. It was Seguin who proved that the gallic acid and the astringent principle are different substances. See Mr. John Thomson's Notes to Fourcroy, vol. iii. 93.

A German apothecary, named Tromer, says, that the excrescences on the roots of young oaks may be used with advantage as a substitute for galls. I believe oak saw-dust has been used instead of galls to produce a black dye.

†† Several processes for procuring this acid may be seen in La Grange's Chymistry, vol. ii. 187.

For the method of analysing astringent vegetable substances, consult Mr. Davy's paper in the Philos. Trans. for 1803.

Every substance, an infusion of which precipitates gelatine, or a

and for medicine: they act an important part in the great elaboratory of nature*: produce that numerous class of bodies called salts: and form many of the rocky and mountainous parts of the globe we inhabit.

Do you recollect any instances of acids entering into the composition of rocks and mountains?

The vast masses of limestone, chalk, and marble, which are found in every part of the world, are combinations of lime and carbonic acid†: the mountains of gypsum in the vicinity of Paris and elsewhere are combinations of lime and the sulphuric acid‡. The fluor spar of Derbyshire owes its compactness, &c. to the fluoric acid§; and there are mountains of common salt both in the eastern and western hemisphere, which contain hundreds of millions of tons of the muriatic acid‖.

Are you sure that the acids which Nature has employed in the formation of mountains are of the same kind as the acids which come under our common notice and observation?

Yes: any of these substances may be decomposed, and their acids exhibited in a state of purity for experiment or use¶.

Do you know of any other natural productions which are indebted to the acids for their natures and properties?

The large masses of alum ores and of ponderous spar in different parts of the earth owe their origin to the sulphuric acid; the chrysolite of Greenland is a compound of alumine and the fluoric acid; and several of the precious stones are combinations of the different earths with the chromic or the phosphoric

* Great advantages have already been obtained from the use of many of the acids in medicine, particularly the mineral acids. As to the *oxygenized muriatic acid*, "I will venture to affirm that it will hereafter be one of the most useful of the materia medica. It is known that it is strongly tonic; that it augments the force of the stomach and the whole system, and acts even as a specific in syphilitic disorders." Fourcroy.

Dr. Thornton says that he has cured syphilitic complaints by nitrous acid, in cases where mercury had failed. Medical Extracts, vol. v. 406. Mr. Cruickshank, of Woolwich, has given it with the same intention, and with the best success.

† Limestone, chalk, and marble, are composed of about 50 parts acid and water, and 50 parts lime.

‡ Gypsum is composed, according to Bergman, of 32 parts of lime and 68 of acid and water.

§ There are some varieties of this salt which contain different portions of acid, but the proportions of their component parts have not yet been ascertained.

‖ Common salt, according to the analysis of Kirwan, is composed of 53 parts soda, 39 acid, and 8 water.

¶ If the pupil be directed to pour a little sulphuric acid upon some pieces of marble, the carbonic acid will be disengaged, and become evident to the senses. In like manner he may disengage the fluoric acid from the fluor spar, the muriatic acid from rock-salt, and other acids from those minerals

acids*; not to mention the annual changes which the vegetable kingdom undergoes by the *formation* and *loss* of the vegetable acids.

You speak of the formation *of acids: Are bodies of this class formed and decomposed by the common operations of nature?*

These bodies are not only formed artificially, as has been before said, by the direct union of their radicals with oxygen, but we have reason to believe that this is perpetually done by *natural* means; and that the acids are the principal agents in those chymical changes which the various substances of this earth are destined to undergo†.

What may we infer from this constitution of things?

From hence we have reason to believe that the great and beneficent Creator has provided such an immense store of all the different *elementary* materials with which this our world is composed, that no scarcity of those things which are subservient to the wants and comforts of its inhabitants could ever happen, whatever changes it might undergo, though it should be destined to revolve in its orbit for millions of years yet to come‡.

in which they are found native. A few experiments of this kind will serve to show him how abundantly the mineral acids occur in Nature.

* Mr. Parkinson thinks that the emerald owes its colour to the oxide of chrome, and the ruby to the acid of that metal. According to Vauquelin, the *ruby* is a combination of the chromic acid, alumine, and magnesia.

The chrysolite seems to be composed of lime and the phosphoric acid. See Ann. de Chim. xxvi.

† "Mr. Baumé, by a series of ingenious experiments, discovered that clays may be produced by the action of the sulphuric acid on vitrified substances. Mr. Ferber applied this fact to the grand operations of Nature on the matters ejected by volcanoes: he discovered a fine white argillaceous matter in the hollow part of vitrified lava, evidently produced by the action of the sulphuric acid. Hence it appears that those substances which have by the action of fire been rendered otherwise intractable, again become, by the action of the sulphuric acid, subservient to vegetable life." Parkinson. See Ferber's Letters.

‡ When we consider the various properties of matter, and the variety of changes it is calculated to undergo for the use, the gratification, and the accommodation of man—we are ready to exclaim—

"We feel the present Deity, and taste
The joy of God, to see a happy world."

CHAPTER VIII.

OF SALTS.

WHAT is a salt?

When an acid* is combined with an alkali, an earth, or a metallic oxide, it forms what is called a salt. Such compounds were formerly called *neutral* salts; but that term is now applied only to those salts in which there is no excess either of acid or of base†.

How many salts are there?

As the acids are capable of forming such various combinations with the different earthy, alkaline, and metallic bases, the precise number of the salts is not known‡. Probably they amount to nearly two thousand§.

* Acids may be considered as true *salifying* principles, and the substance with which they unite to form salts may be called salifiable *bases*. Lavoisier.

† To give the pupil a clear idea of this class of bodies, it may be adviseable to set him to form some of the salts from their component parts. He might be directed to pour a little sulphuric acid into a solution of soda in water, to evaporate the superfluous water, and then to notice the crystallization of the new formed salt; if the liquor be allowed to stand quietly for a few hours in a cool place, he may observe the salt shoot into beautiful crystals of sulphate of soda.

‡ Fourcroy reckons that there are 134 *species* of salts; but how many *distinct* salts there are he has not calculated.

Having 52 acids and 57 bases, it would appear at first sight that there are 1824 salts: but there are several of the metallic oxides which cannot combine with many of the acids; which is also the case with silex, one of the earths. However, to compensate this deficiency, there are several acids capable of combining with two bases at once. These are called *triple-salts*. Besides these there are super-salts, and sub-salts. Thomson.

§ Should any one express his surprise that the number of *one* class of bodies should be so great, he may be told that Nature seems to aim at variety in all her productions. Saint Pierre informs us that there are 6000 species of flies, and 760 different butterflies. Ray computed the number of spe[illegible] nsects at ten thousand. There are are above 1000 different species c[illegible] Great Britain.

What method has been taken to distinguish the different salts?

Modern chymists have adopted a new nomenclature for this purpose, which is simple, ingenious, and useful*.

How are the salts distinguished by this nomenclature?

Every salt has a double name, one part of which indicates its acid, and the other its base; so that in a collection of many hundred different salts, the composition of each is immediately known by its appellation.

Can you explain the manner in which this is effected?

All substances which are compounds of metallic oxides, earths, or alkalies with the sulphuric acid, are called *sulphates*; with the muriatic acid, *muriates*; with the nitric acid, *nitrates*; with the carbonic acid, *carbonates*, &c. &c.

Do the advantages which we derive from this nomenclature compensate for the inconvenience of changing the names of so many substances?

The new nomenclature, by its classification of bodies, gives such a facility to the acquisition of chymical knowledge, that this alone would have been sufficient to have justified chymists in adopting it; but its contrivance for pointing out the nature of the substances bearing the new names, gives it advantages far surpassing every inconvenience attending the alteration†.

Do describe the nature of some of these advantages.

The saline compound, formerly called *Glauber's* salt, is now called *sulphate of soda*, for it is a combination of sulphuric acid and soda‡; what was called *gypsum*, or plaister of Paris, a compound of lime and sulphuric acid, is now called *sulphate of lime*; in like manner what was called *green copperas*, is now *sulphate of iron*, that substance being a compound, not of *copper*, as the old name seemed to import, but of *iron* and the sulphuric acid§.

Have the framers of this nomenclature been equally happy in the

* This nomenclature was drawn up by a society of French chymists, soon after the new theory of chymistry was announced by Lavoisier; and most of the French writers arrogate great honour to their nation, on both these accounts. But it may very fairly be remarked, that had it not been for the *previous* discoveries of Dr. Black, Dr. Priestley, and Mr. Cavendish,—Lavoisier, in all probability, would not have had the honour of enlarging the boundaries of chymical knowledge.

† As the boundaries of chymical science have been extended, the number of known salts has been surprisingly increased; so much so, that it would have been impossible for any memory to recollect the nature of each, without the assistance of a nomenclature of this kind.

‡ It is necessary to remark, that when an acid is combined with *two* bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumine and potash, and tartrate of potash and soda.

§ It would be easy to make out a long list of substances with names equally improper, and which have characteristic and appropriate names assigned them in the new nomenclature.

choice of names for the salts which are composed with the other acids?

Yes: the principle upon which the nomenclature is formed is such, that the composition of every salt is designated by an appropriate name with the utmost perspicuity.

According to the new nomenclature, what is the common culinary salt called?

Common salt is called *muriate of soda**; that is, a composition formed of soda and muriatic acid.

What do you call salt-petre?

Salt-petre is called *nitrate of potash*; being composed of potash and nitric acid.

What is chalk now called?

Chalk, being a compound of lime and carbonic acid, is called *carbonate of lime.*

You have said that these bodies were formerly called neutral *salts, why is not that term now applied as before?*

No salt can strictly be called *neutral*, except such in which the acid is completely neutralized by the base, and the base by the acid, so as to be mutually saturated by each other†.

Is not that the case with all saline compounds?

No: some have an excess of acid, as cream of tartar; and other salts have an excess of base, as common borax.

How are such salts distinguished?

When a salt is found to contain an excess of acid, the preposition SUPER is prefixed to its name‡; but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added; as super-tartrate of potash, and sub-borate of soda§.

In the chapter on acids, it was said that those which are not completely saturated with oxygen acquire different properties from that circumstance, and form very different salts to those which are composed with

* Formerly the word SALT was confined to muriate of soda. No other substance was then known as a salt. Afterwards, the acids and alkalies were called salts also. There are innumerable proofs of this in the old chymical writings.

† The propriety of restricting the use of the term *neutral* will appear, if we consider that we have some bases that combine with more than one dose of acid, and thereby form salts which differ in their appearance and properties. Thus we have *sulphate* of potash, and *super*-sulphate of potash. The one is a neutral salt, the other is a salt with excess of acid.

‡ Many of these super salts may be discovered by carbonate of magnesia. If an acid be present in the solution, an effervescence will take place on the addition of the carbonate.

§ We are indebted to Dr. Pearson for this mode of distinguishing these salts. Before this method was adopted, the former of these salts was called tartrate of potash with excess of acid, or acidulous tartrate of potash; and the latter borate of soda with excess of base.

acids fully oxygenized. When salts are formed with such acids, what are they called in the new nomenclature?

All salts composed with the acids ending in *ous*, take an ending in *ite*, instead of *ate*. Thus *sulphite*, *phosphite*, instead of *sulphate* and *phosphate**.

Have you enumerated all the advantages of the new nomenclature?

No: it likewise enables chymists to class the different salts with a systematic arrangement which was before impossible; and to describe the properties and characters of each genus with clearness and precision.

What are the generic characters of the SULPHATES?

The sulphates† have generally a bitter taste; are precipitable from fluids by a solution of barytes and afford sulphurets when heated red hot with charcoal‡.

Can you enumerate a few of the principal sulphuric salts?

Among the first of them are sulphate of barytes§, sulphate of

* When sulphur is fully saturated with oxygen it forms what is called sulphuric acid, and the salts composed with this acid are called sulphates. But when sulphur is partially oxygenized, an acid is produced called sulphurous acid, and the salts formed with it are called sulphites.

The new nomenclature enables us to distinguish between acids which are partially oxygenized, and those which contain a maximum of oxygen. This is of great importance, because the properties of the salts formed with these acids vary as much as the acids themselves. The salts formed with acids ending in *ic* are generally permanent; whereas salts formed with the same bases combined with acids ending in *ous* are seldom permanent, but by exposure to the air attract oxygen, and are changed into salts of the former kind.

† The quantity of sulphuric acid contained in any of the sulphuric salts may be known by means of muriate of barytes. If a solution of muriate of barytes be added to a solution of any of the sulphates, a sulphate of barytes will be instantly formed and precipitated. When this precipitate is dried, every hundred grains of it will (according to Chenevix) contain 24 grains of sulphuric acid.

‡ When a sulphate has been converted to a sulphuret by burning with charcoal, the sulphuret may be decomposed, and the sulphur precipitated by the addition of muriatic acid. For a method of decomposing these salts in a large way, consult Encyclopædia Britannica, Chymical Index, article Vitriolated Tartar.

To analyse the earthy sulphates, heat them to whiteness, in order to find the quantity of water which they contain, then boil them with carbonate of potash, which will occasion their decomposition. A common Florence oil flask is sufficient for this purpose. It may be ascertained when it has been sufficiently boiled by taking a little of the earth from the bottom of the flask, and trying it with muriatic acid. If the muriatic acid dissolves it entirely, the decomposition is complete.

§ Sulphate of barytes, or *ponderous spar* as it has been called, is abundant in different parts of the earth. Sulphate of strontian is found in Scotland and elsewhere in abundance. Sulphate of potash, sulphate of soda, and sulphate of ammonia are prepared by chymical manufacturers in many of their processes. Sulphate of lime, sulphate of magnesia, and sulphate of

strontian, sulphate of potash, sulphate of soda, sulphate of ammonia, sulphate of lime*, sulphate of magnesia, and sulphate of alumine†.

What are the generic characteristics of the SULPHITES?

The sulphites yield sulphur, and become sulphates in the fire; they have a disagreeable sulphureous taste; burn by the contact of the sulphuric, nitric, or muriatic acid; and are changed into *sulphates* by mere exposure to atmospheric air‡.

Can you enumerate some of the sulphurous salts?

The principal are, sulphite of barytes, sulphite of potash, sulphite of soda, sulphite of ammonia, sulphite of lime, sulphite of magnesia, and sulphite of alumine§.

What are the generic characteristics of the MURIATES?

The muriates, when acted upon by concentrated sulphuric acid, yield a white vapour of muriatic acid; and when by the nitric acid, oxygenized muriatic acid gas. They are the most volatile, and yet the least decomposeable by fire, of all the salts; not being perceptibly altered by combustibles, even when assisted by heat||.

Can you enumerate the chief of the muriatic salts?

The principal are: muriate of soda¶ muriate of potash, muri-

are native productions. Sulphate of ammonia, it has been said, has been found native in the neighbourhood of volcanoes.

* Sulphate of lime is gotten in abundance in Staffordshire, Derbyshire, and other counties of England. The hills round Paris are entirely composed of this earthy salt. Hence its name *plaister of Paris*. When burnt and ground it is miscible with water, for which it has so great an affinity that it becomes solid almost immediately. This property renders it a fit substance for forming busts, cornices, &c. In America this substance is used as a manure.

† Vauquelin distinguishes seven different kinds of sulphate of alumine.

‡ See a memoir on these salts by Fourcroy and Vauquelin, in vol. xxiii. of Ann. de Chimie.

§ The *sulphites* were first pointed out by Stahl. Sulphite of potash was the first of these salts that he examined. From this circumstance it acquired the name of sulphureous salt of Stahl.

These salts are mostly formed artificially. The method employed may be seen in Thomson's Chymistry, vol. ii. 449.

|| This is an evident, and at the same time a most remarkable character of this species of salt. Muriate of soda may be volatilized by heat, but if the vapour be collected it will be found to be still muriate of soda. Some years ago I exposed several hundred weights of this salt to a most intense heat in a reverberatory furnace for 48 hours, with a view to decompose it; but when it was removed from the furnace it was found to be muriate of soda still. Another portion was kept in a state of fusion for 36 hours with a considerable quantity of carbonaceous matter, but no decomposition was effected.

¶ Muriate of soda is the salt which has been longest known. It is our common culinary salt, and is chiefly useful in furnishing a supply of soda to preser[illegible] le in an alkaline and antiseptic condition.

ate of ammonia, muriate of barytes, muriate of strontian, muriate of lime, and muriate of magnesia*.

What are the generic characteristics of the HYPEROXYGENIZED MURIATES†?

The hyperoxygenized muriates yield very pure oxygen gas by the action of fire, and are thus converted to common muriates: the strong acids expel the hyperoxygenized muriatic acid from these salts, without the assistance of heat‡. When mixed with

This salt is of great use in the animal creation; horses are very fond of it; cows give more milk when supplied with it: and Dr. Mitchel relates, that in the back settlements of America, wherever this salt is found to abound, thither the wild beasts of the forests assemble to regale themselves; and that some of these places are so much frequented, that the ground is trodden to mud by them. See his letter to Dr. Mosely, Phil. Mag. vol. xx. 98. The natives call these spots *licks*, or licking-places. In some parts of Africa, large herds of cattle travel from great distances at stated seasons to enjoy the marine plants which grow on the coast and are saturated with sea salt. The fattening property of our own salt marshes is well known to graziers and farmers.

Whenever the finances of this country are in a state to allow the duty to be withdrawn, the greatest improvements in agriculture may be expected from this salt. Mr. le Goux, in his history of the cocoa-nut tree, tells us that the inhabitants of those parts of Hindostan and China, which border on the sea-coast, sprinkle their rice-fields with sea-water, and use no other manure; and that in the interior of these countries they sprinkle the lands with salt before they are tilled; and that this practice has been followed for ages with the greatest advantage.

* Muriate of potash has been found native in the bogs of Picardy: it was formerly much used by the alum-makers to procure the crystallization of alum. Muriate of ammonia is the common sal-ammoniac of commerce. Muriate of barytes and strontian are both factitious salts. Muriate of lime is found native in various states: it is also furnished in abundance by the makers of carbonate of ammonia: it is used for the production of artificial cold. When dissolved in alcohol it burns with a flame of a beautiful red colour, especially if the solution be agitated during the inflammation. Muriate of magnesia is found in mineral and sea waters.

† This species of salts was discovered by Berthollet in 1786.

‡ Those salts which have been called oxygenized muriates have been proved by Mr. Chenevix to be hyperoxygenized muriates; that is, the acid which forms these salts is in the highest degree of oxygenizement. He was desirous of exhibiting this acid in a separate state: but when he attempted to obtain it from only 500 grains of hyperoxygenized muriate of potash, the retort burst with a loud report, and was reduced almost to powder; so that scarcely any fragment of it could be found in the laboratory. Dr. Vandier, who was present, was near losing his sight by the explosion. Phil. Trans. vol. xcii. 126.

The component parts of this salt are,

Hyperoxygenized muriatic acid	58
Potash - - - - -	39
Water - - - - -	3
	100

combustibles, they detonate with great violence by mere friction or percussion, and sometimes spontaneously*.

Can you enumerate the hyperoxygenized muriates?

The chief are: the hyperoxygenized muriate of potash†, hyperoxygenized muriate of soda, hyperoxygenized muriate of barytes, and the hyperoxygenized muriate of lime.

What are the generic characteristics of the NITRATES?

The nitrates yield impure oxygen gas mingled with nitrogen gas by the action of fire; they give out a white vapour of nitric acid when acted on by concentrated sulphuric acid; and when mixed with combustible substances produce at a red heat inflammation and detonation‡.

Can you enumerate some of the nitric salts?

* Fourcroy remarks of it, that "it seems to include the elements of thunder in its particles. A chymist can produce effects almost miraculous by its means, and Nature seems to have concentrated all her power of detonation, fulmination and inflammation in this terrible compound." By triturating *gently* 3 grains of this salt and one of sulphur in a mortar with a metallic pestle, a series of detonations takes place resembling the cracks of a whip. If struck on an anvil, the report is as loud as a gun. But too great caution cannot be exercised in the use of this salt. Three parts of it with half a part of sulphur and half a part of choarcoal produce most dreadful and violent explosions. But the shocking death of two individuals in October 1788, and the burns which others have suffered by it, render it feared by chymists in general. If the aforesaid mixture of this salt be thrown into concentrated sulphuric acid, a flame is developed so strong and brilliant that the eye can with difficulty support it. Fourcroy, vol. iii. 313. It should be remembered that the mixture must always be made moist, and never kept *ready* mixed, as it is liable to explode spontaneously.

† Hyperoxygenized muriate of potash, which is prepared by art, is used in medicine and for other purposes. If mixed with sulphur or charcoal it detonates violently. Hence Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it.

Dr. Thomson, vol. ii. 432. Phil. Trans. xcii. 128.

Berthollet is of opinion that in this salt the oxygen retains all the caloric which it had when in a gaseous state. The concentration of the oxygen by its union with the potash is probably sufficient to account for its explosive effects.

A solution of this salt well mixed with common soap in a mortar, is said to improve the soap so as to render it fitter for shaving than any of the kinds recommended for that purpose.

The other hyperoxygenized muriates are prepared also by art, and are of little use, except the hyperoxygenized muriate of lime, which is employed in bleaching.

‡ This may be shown by heating a little nitre in a crucible, and throwing powdered charcoal upon it. The charcoal will combine with the oxygen of the acid, and pass off in the state of carbonic acid gas.

The more noted are; nitrate of potash*, nitrate of soda†, nitrate of ammonia, nitrate of barytes, nitrate of strontian, nitrate of lime‡, and nitrate of magnesia.

What are the generic characteristics of the CARBONATES?

Some of the carbonates are soluble in water, and all of them give out carbonic acid gas with a brisk and rapid effervescence, when treated with the stronger acids§.

Endeavour to enumerate the carbonic salts.

The carbonate of barytes‖, carbonate of strontian, carbonate of lime¶, carbonate of potash, carbonate of soda, carbonate of magnesia, and carbonate of ammonia, are the principal carbonates that occur.

* Nitrate of potash, or salt-petre, is produced by nature in abundance, particularly in the East: it appears that nothing is necessary for its production but the presence of lime, heat, and dry atmospheric air. The atmosphere furnishes the acid; but how the potash is given to it is not known.

There is a natural nitre-bed in Apulia in Naples, in which the earth contains 40 per cent. of nitre. Pelletier has published a memoir on the analysis of this valuable treasure, in the Annales de Chimie, tome xxiii.

In Switzerland, the farmers extract an abundant quantity of very fine salt-petre from the earth under the stalls of their cattle. The urine of quadrupeds contains much potash, and this acquires nitric acid from the atmosphere. See Additional Notes, No. xxii.

Nitre is used in large quantities in the manufacture of gunpowder, which is composed of 76 parts nitre, 15 charcoal, and 9 sulphur, in every 100 parts of gunpowder. The best account we have of this manufacture was published by Mr. Coleman, the superintendant of the Royal Powder-mills, in the Phil. Mag, vol. ix. 355.

When it is considered that nitre was known, and in use *long before* it was distilled for aqua-fortis, or employed in the manufacture of gunpowder; what encouragement does this afford to chymists, to investigate the properties of every new substance which comes under their observation?

† Nitrate of soda, according to Bowles, has been found native in Spain.

‡ Nitrate of lime is generally found native with salt-petre. If melted over the fire it becomes luminous, and forms what is called Baldwin's phosphorus.

§ There are eleven species of carbonic salts at present known. There are only four species of native earths or stones which are combined with carbonic acid; viz. lime, barytes, strontian, and magnesia.

Crystallized carbonate of lime may be known by its lightness, and by being found in rhomboids. Its specific gravity is only 3.00, being the lightest of all the earthy salts.

‖ Carbonate of barytes was found native by Dr. Withering in 1783. It will probably become useful in the arts, as it is not so scarce and dear as it was formerly. Carbonate of strontian is found native at Strontian in Scotland; carbonate of lime exists native in a variety of states in great abundance: the other carbonates are in general formed artificially.

¶ Carbonate of lime is not soluble in water, unless the water itself be charged with carbonic acid. It is thus that nature dissolves calcareous masses: and it is owing to this that stalactites and other incrustation formed. See page 99—100.

*What are the generic characteristics of the PHOSPHATES?**

The phosphates are fusible either into opaque or transparent glasses; are phosphorescent at a high temperature; are soluble in nitric acid without effervescence; and are precipitable from their solutions by lime-water

Which are the chief phosphoric salts?

Phosphate of lime†, phosphate of soda‡, phosphate of ammonia§, and the phosphate of soda and ammonia, formerly called microcosmic salt‖.

What are the generic characteristics of the PHOSPHITES¶.

The phosphites yield a phosphorescent flame when heated; and in a strong fire give out a portion of phosphoros, which converts them into phosphates**. They are fusible by a violent heat into glass.

Endeavour to enumerate the principal phosphites.

The principal phosphites are; phosphite of barytes, phosphite

* The only phosphoric salt which is found native is the aparite, or phosphate of lime, which is found in abundance in many parts of the world.

† Phosphate of lime is found in bones, milk, and some other animal matters. See Note, page 104. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed of phosphoric acid 41 parts, lime 59. It is prescribed by the French physicians as a specific in the rachitis, to diminish the effects of acids which soften the bones. Fourcroy, vol. iii. 346. See Bonhomme's paper on this subject in Annales de Chimie, tome xvii.: the cases which he adduces are extremely curious.

Phosphate of lime exists also in the farina of wheat. La Grange remarks, that a person who eats a pound of farina a day will swallow 3 pounds 6 ounces 4 drams, and 44 grains of phosphate of lime in the year. Was not this designed by nature as a means of repairing the loss which our bones perpetually sustain? It is a curious fact, that wheat *straw*, which was not intended for the food of man, contains *carbonic* of lime and not phosphate.

It is remarkable, that, though phosphate of lime is always found in the urine of adults, this salt is not evacuated by infants. The rapid formation of the bones in the first periods of life requires that there should be no waste of any of the phosphoric salts; and Nature, ever provident, has provided accordingly.

‡ Phosphate of soda is formed artificially. It was first made and recommended by Dr. Pearson. This salt is used in medicine as a cathartic, and is much pleasanter than either Glauber or Rochelle salts. It forms very distinct small crystals; and is used by some manufacturers as a flux instead of borax.

§ Phosphate of ammonia is found in urine, and is also prepared by art to be used as an ingredient in making pastes to imitate precious stones. It is one of the best fluxes for experiments with a blow-pipe.

‖ Phosphate of soda and ammonia is found in human urine, from whence it may be procured by evaporation in the state of a triple salt.

¶ None of these salts have been found in nature; they are all formed artificially, but they have not yet been brought into use. Fourcroy distinguishes eleven species of the earthy and alkaline phosphites.

** The affusion of nitric or oxygenized muriatic acid will convert these salts to phosphates.

of lime, phosphite of magnesia, phosphite of potash, phosphite of soda, and phosphite of ammonia*.

What are the generic characteristics of the FLUATES?

The fluates are weak salts, yielding, with concentrated sulphuric acid, a vapour which corrodes glass. The are not decomposable by heat, nor altered by combustibles†.

Which are the chief fluoric salts?

Fluate of lime‡, fluate of soda, fluate of silex, and fluate of alumine.

What are the generic characters of the BORATES?

The borates are all fusible into glass; and with most of the metallic oxides, form glass of different colours§. Their concentrated solutions afford, by the strong acids, pearly crystals of boracic acid.

Can you enumerate the boracic salts?

* This salt exhibits several curious appearances when treated with caloric. For particulars, consult Fourcroy.

† These salts were first made known by Scheele in 1771. Some of them phosphoresce when heated.

‡ Ten varieties of fluate of lime have been found. They are of different colours, owing to the different degrees of oxidizement of the iron which they contain. If any of these coloured fluates be pulverized, and then heated on a shovel, they will emit a violet phosphoric light, the cause of which is not known. We have no means of dissolving fluate of lime in water: but nature dissolves it by some unknown process; for it is found in crystals, combined with its water of crystallization. This crystalline substance, which is known by the names of Derbyshire spar and Blue John, is used in making ornamental vases, &c. It is of various colours, and bears an excellent polish. Where there are flaws or cracks in the mineral, I am told the workmen have an ingenious method of filling them up with lead ore, which they execute so well, that it cannot be discovered but by very close examination.

According to one of the last numbers of the Annales de Chimie, it appears that fluoric acid is found to form part of the human teeth, and is probably combined with lime. It may be conjectured that this was a contrivance of nature, to give more durability to these important organs than they would have had by phosphate of lime only.

Fluate of lime is very abundant in nature. It is often found in beautiful octahedral or cubical crystals. The other fluates are factitious salts, except fluate of alumine, which has been lately found in Greenland, in a mineral called the *crysolite of Greenland*. It contains a large portion of soda.

§ It is to the property which these salts possess of fusing mineral substances and metallic oxides, that they are used by braziers, tin-men, &c. Sub-borate of soda is employed by chymists to fuse those stones which cannot be brought into fusion by the alkalies. In analysing stones and minerals, the great art is to bring them into solution. When this is effected, their component parts may be readily separated by the different chymical re-agents.

Mr. Chenevix was unable to liquefy corundum by any means till he made use of borate of soda.

The principal are; sub-borate of soda*, borate of lime†, borate of magnesia‡, and borate of potash.

What is the distinguishing characteristic of the ARSENIATES?

When heated with charcoal they are decomposed, and arsenic sublimes, which is known by its alliaceous or garlic smell.

Which are the chief salts formed with arsenic acid?

Arseniate of barytes, arseniate of lime, arseniate of magnesia, arseniate of potash, arseniate of soda, and arseniate of ammonia§.

What are the characters of the TUNGSTATES?

The salts called tungstates are combinations of the yellow oxide of tungsten with the alkalies and earths. Most of them have a metallic and caustic taste‖.

Which are the principal salts formed with the tungstic acid?

Tungstate of potash, tungstate of soda, tungstate of ammonia, tungstate of lime¶, and tungstate of magnesia.

What are the generic characteristics of the ACETATES?

The acetates are all very soluble in water; are decomposed by the action of heat; and afford acetic acid when distilled with sulphuric acid.

*Which are the chief acetic** salts?*

Acetate of barytes, acetate of potash, acetate of soda, acetate of lime††, acetate of ammonia‡‡, and acetate of magnesia.

* This salt, which is the common borax of commerce, is called sub-borate, because it contains an excess of soda. According to Bergman, it requires half its weight of boracic acid to bring it to the state of a neutral salt. It is generally brought from the East Indies in a state of impurity. The article is then called *tincal*. Borax has also been found near Lunenburgh, in the dutchy of Brunswick, in a mountain of gypsum.

Borax is found also at the bottom of pools of stagnant water, in the kingdom of Thibet. A particular account of the management of the natives in procuring it may be seen in Dr. Anderson's Bee, vol. xvii. 22.

† What is called cubic quartz is a borate of lime and magnesia.

‡ Borate of magnesia has been found near Lunenburgh. The other borates are factitious salts.

§ Most of these salts are formed artificially; few of them are used in the arts; though some of them have been employed in calico printing. They were first formed by Macquer.

‖ We owe to Scheele the discovery of these salts. They have lately been described with great accuracy by Vauquelin in Journal des Mines, No. xix.

¶ Tungstate of lime, which is found native, is well known to mineralogists: the other tungstates are formed by art.

** Acetate of potash, acetate of soda, and acetate of ammonia, have long been known and prepared for medicinal uses; the other acetates have not yet come into use. Acetate of potash was known and described by Raymond Lully.

†† According to Pliny, acetate of lime was used by the ancients in surgery. Lib. xxxvi. cap. 24.

‡‡ A solution of this salt has been long known in pharmacy under the name of *Mindererus's spirit*.

What are the generic characteristics of the OXALATES?

The oxalates are decomposeable by a red heat; lime-water precipitates a white powder from their neutral solutions, which powder is soluble in acetic acid, after being exposed to a red heat. The insoluble oxalates are rendered soluble by an excess of the more powerful acids*.

Can you enumerate the principal oxalic salts?

Oxalate of lime, oxalate of barytes, oxalate of potash, oxalate of soda, and oxalate of ammonia†.

What are the generic characteristics of the TARTRATES?

When the tartrates are exposed to a red heat, the acid is decomposed, and the base remains. The earthy tartrates are less soluble than the alkaline, but they are all capable of combining with another base, and forming triple salts.

Can you enumerate the principal tartaric salts?

Tartrate of lime‡, tartrate of strontian, tartrate of potash, tartrate of potash and soda, and tartrate of potash and ammonia.

What are the generic characteristics of the CITRATES?

The citrates are decomposed by the strong mineral acids; the oxalic and tartaric acids also decompose them, and occasion an insoluble precipitate in their solutions; and when distilled they yield traces of acetic acid.

Which are the principal citrates?

Citrate of barytes, citrate of lime, citrate of potash, citrate of soda, and citrate of ammonia§.

What are the generic characteristics of the CAMPHORATES?

The camphorates have generally a bitterish taste; they are decomposeable by heat, and burn with a blue flame.

* This genus of salts was first made known by Bergman in his dissertation on oxalic acid.

† Oxalate of lime is one of the compounds most frequently found in human calculi. Vauquelin, Annales de Chimie.

Oxalate of potash is prepared in England in considerable quantities for the calico-printers. It is found ready formed in the juice of *wood-sorrel*, in the state of a superoxalate. The other oxalates are not yet come into use.

‡ Tartrate of lime is found in the tartar of commerce; and it is also formed by art, by adding lime to a solution of tartar in boiling water. This latter salt is procured from the inside of wine casks, and is used in large quantities by dyers and other manufacturers, both in its crude and refined state. In the former it is called argol, and in the latter cream of tartar; both these articles contain an excess of acid, and therefore are properly *super*-tartrates of potash. Tartrate of potash and soda is what is usually called Rochelle salt, or sel de Seignette; it is formed artificially by adding soda in crystals to a solution of cream of tartar, till the excess of acid is saturated. The other tartrates are made without any view to their use in the arts.

§ These salts are all formed artificially. Citrate of potash is used much in medicine, and is called *saline draught*. The other citrates are not yet found to be of any use.

Which are the principal camphorates?

Camphorate of lime, camphorate of potash, camphorate of soda, camphorate of barytes, camphorate of ammonia, camphorate of magnesia, and camphorate of alumine*.

What are the generic characters of the SUBERATES?

The several suberates differ so much in their properties, that it would be difficult to characterise the genus otherwise than by saying that they generally possess a bitter taste, and are decomposeable by heat.

Which are the principal suberates?

Suberate of barytes, suberate of potash, suberate of lime, and suberate of ammonia†.

What are the generic characters of the PRUSSIATES?

The prussiates are so variable in their characters, and so easily altered, that little attention has been paid to their real nature. In the alkaline prussiates the acid is united so feebly as not to destroy their alkaline properties. The triple prussiates are those most known, and of most use to chymists.

Which are the principal prussiates?

The prussiates of iron, prussiate of lime and iron, and the prussiate of potash and iron, formerly called prussian alkali‡.

How are these different salts known from each other?

They are known by the figure of their crystals§, by their taste, by their fusibility, and other marks, which are called their *specific* characters, and which have been discovered by chymists for distinguishing them.

What is meant by the figure of their crystals?

There is a great variety in the form of crystallized salts; each salt during crystallization preserving its own peculiar form||.

* These salts, which have not been applied to any useful purpose, are also all formed artificially. For an account of their properties, consult Bouillon la Grange, or any system of chymistry.

† These salts, which are all factitious, are likewise not yet brought into use.

‡ The prussiates are all made by art, but the class is very interesting. There are four different prussiates of iron, which differ from each other in consequence of the different degrees of oxidizement of the iron. Prussiate of lime and iron is used as a test to ascertain the presence of metals held in solution. Prussiate of potash and iron, known by the name of *prussian alkali*, is the best combination of the prussic acid for the same purpose, especially for detecting the existence of iron. It is of the utmost importance to chymists as a re-agent. For the best method of preparing this test, consult Dr. Thomson.

§ The best work on this subject is, I believe, that of the Abbé Hauy, to which I refer the student.

|| When, either by the diminution of the quantity of liquid, or the reduction of the temperature, the force of cohesion causes a separation of a portion of the dissolved substance, in almost all cases the parts which are

Thus, common culinary salt always crystallizes in small cubes, and sulphate of soda in six-sided prisms.

How is the crystallization of salts effected?*

When a certain portion of the water is evaporated from a saline solution, and the remainder left at rest, the salts will shoot into crystals, and will be found dispersed through the mother water at the bottom and at the sides of the vessel†.

What is meant by mother water?

Mother water is the liquor which remains after a salt has combined with its portion of water necessary for crystallization. By further evaporation and cooling ‡ mother waters generally afford a fresh portion of salt.

separated form a regular arrangement; owing to the relation between their figure and their reciprocal affinity.—Hence those crystals which Nature offers in such variety, and which are produced in so great a number of chymical combinations.

The plates which continue to be added (either because the crystal acts on the dissolved substance, or because the cause of the separation continues to exist in the liquid) are composed of moleculæ similar to the first, and continue to augment the bulk of the crystal, preserving its first form; nevertheless, this increase may be determined to one face in preference to another, according to the position of the crystal and the circumstances in which the solution is found. Berthollet's Chymical Statics.

* Crystallization is effected by means of water or caloric, one of which is necessary to keep the parts of the substance in a state of minute division. In order that regular crystallization may take place, it is necessary that the fluid, whether water or caloric, or both, should be subtracted gradually. This gives an opportunity for the parts of the substance to unite regularly, according to their several attractions, and to produce regular crystals; whereas, a sudden abstraction of the fluid causes the particles often to unite in a shapeless mass.

Sir Isaac Newton seems to have had a very clear idea of the cause of crystallization. "When," says he, "a liquor saturated with salt is evaporated to a pellicle, and sufficiently cooled, the salt falls in regular crystals. Before being collected, the saline particles floated in the liquor, equally distant from each other; they acted therefore mutually on each other, with a force which was equal at equal distances, and unequal at unequal distances; so, in virtue of this force, they must arrange themselves in an uniform manner." Opt. book iii.

† In large laboratories the salts of commerce are prepared by evaporation and cooling, but it is necessary to vary the process for almost every different kind of salt. So much nicety is necessary, that many manufacturers are much perplexed by this part of their business, till they have established each process on the basis of experiment.

Some valuable directions for crystallizing salts may be found in Dr. Campbell's paper, in Nicholson's Journal, 8vo. vol. ii. 117. See also Le Blanc's directions in same work, vol. i. 191. also the Encyclopædia Britannica, vol. iv. 443.

‡ For boiling down saline liquors in the large way, leaden boilers, or boilers made with plates of sheet iron rivetted together, are the most proper. The plates, I speak from experience, should not be more than nine inches wide, made of the best tough *hammered* iron, three-eighths of

What is the cause of the crystallization of salts?

The crystallization of salts is owing to their forming a chymical combination with a portion of the water in which they are dissolved; in which combination the water parts with its caloric, and takes a solid form*.

What is the water called which combines with salts during their crystallization?

It is called the water of crystallization†.

What quantity of water do salts combine with during their crystallization?

The quantity of water varies very much in different salts; for though some salts take up very little water, others combine with more than their own weight, which is the case with alum, carbonate of soda‡, and others.

thick in the middle, and one fourth of an inch thick at their edges. If made with plates wider or thinner, the bottom will warp, and soon become useless. Common rolled iron will be sufficient for the sides. These pans are manufactured best in Lancashire and Cheshire, where there is a great demand for them for the salt wiches. Boilers of *cast* iron would crack by the adhesion of the salt to them.

* It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly grain tin. Nothing can exemplify this kind of crystallization better than muriate of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. (See Additional Notes, No. xxiii.) If glass be kept in a red heat for a long time and cooled gradually—instead of being the transparent body we generally see it—it will crystallize like metals. Starch is another instance of *dry* crystallization. Probably these dry crystallizations are all owing to the shrinking of the substances by the loss of caloric. Dr. Garnet accounts for the origin of basaltes in this way: (See his Tour to the Western Isles.) The Giants' Causeway in the county of Antrim, in Ireland, is the most stupendous natural curiosity of this kind in the world. It is formed of perpendicular pillars of basaltes, which stand in contact with each other. The pillars are irregular prisms of various forms, from three to nine sides; but they are principally hexagons. The appearance of the whole is as neat as it is magnificent. The columns at Fairhead are 250 feet high, arranged in the utmost regularity and order; from the base of which to the level of the sea there is a precipitous declivity of at least 300 feet, making together a perpendicular height of 550 feet. For a further account of this most astonishing natural curiosity, I refer the reader to "The honourable Mrs. Murray's Companion to the Western Highlands of Scotland," and to "Dr. Richardson's Observations," in Nicholson's Journal, vol. v. 4to. 321.

Basalt is used now in the manufacture of glass bottles. If calcined and pulverized it imparts to mortar the property of hardening under water.

Rees's Cyclopædia.

† This water *solidifies* as the salt crystallizes, and becomes itself a part of the salt. When abstracted from salts, it is found to be as pure as distilled water.

‡ Take a portion of sulphate of soda (Glauber's salt) and dry it over a common fire, which will reduce it to less than half its weight. Dissolve

Are salts as unalterable in their appearances as their chymical properties?

No: *crystallized* salts are liable to changes in their appearance by exposure to atmospheric air*. Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

What is meant by the DELIQUESCENCE *of a salt?*

Some salts have so great an affinity for water, that they absorb it with avidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, by exposure to atmospheric air†.

What is meant by the EFFLORESCENCE *of a salt?*

Some salts having less affinity for water than atmospheric air has‡, lose their water of crystallization by exposure to atmospheric air, and fall into powder: such salts are said to effloresce. Carbonate and sulphate of soda are good examples.

this dried salt in three times its weight of boiling water, set the liquor aside, and, when cold, beautiful crystals resembling the original crystals will be found in the liquor. By an attentive examination of the liquor, the crystals may be seen to form as the liquor cools. This is a cheap and easy experiment, and may be exhibited to the pupil as an example of crystallization in general.

* A Table of the Action of Atmospheric Air on Salts.

Potash	Deliquesces	Nitrate of potash	None
Soda	Sub-deliquesces	—— soda	Sub-deliquesces
Carbonate of potash	If in crystals, none	—— ammonia	Agglutinates
—— soda	Effloresces	—— barytes	Slightly efflorescent
—— ammonia	None	—— lime	Deliquesces
—— lime	None	—— magnesia	Deliquesces
—— magnesia	None	Muriate of potash	None
Sulphate of potash	None	—— soda	None
—— soda	Effloresces	—— lime	Deliquesces
—— lime	None	—— ammonia	Sub-deliquesces
—— ammonia	Sub-deliquesces	—— barytes	None
—— magnesia	Effloresces	—— magnesia	Deliquesces.

† Some of these salts have so little force of cohesion, that the action of water, however small the quantity, is sufficient to prevent their crystallization; but alcohol having a greater affinity for water than the water has for these salts, the action exerted on them by the water is diminished by the addition of alcohol, and crystallization takes place. This shows that they do possess in themselves an active cohesion of parts. Berthollet.

‡ Muriate of barytes, muriate of soda, and some other salts seem to have exactly the same affinity for water that atmospheric air has. Such salts neither effloresce nor deliquesce by any exposure to the atmosphere.

Are salts capable of any other changes besides efflorescence and deliquescence?

Yes: salts have the properties of solubility*, and fusibility.

What is meant by the SOLUBILITY of a salt?

Salts in general have the property of dissolving in water; but the different salts possess different degrees of solubility†.

What is meant by the FUSIBILITY of these salts?

Salts have not only the property of dissolving in water, but will melt by exposure to great heat. The different salts require different degrees of heat to put them in a state of fusion‡.

Have the different salts any action upon each other?

Yes: we have many instances of salts mutually decomposing each other.

* Table of the Comparative Solubility of some of the Common Salts.

SALTS.	Solubility in 100 parts of water. at 60°.	at 212°.	SALTS.	Solubility in 100 parts of water. at 60°.	at 212°.
Sulphate of potash	6.25	20.	Muriate of potash	33.	
——— soda	37.	125.	——— soda	35.42	36.16
——— lime	0.2	0.22	——— lime	200.	
——— ammonia	50.	100.	——— ammonia	33.	
——— magnesia	100.	133.	Carbonate of potash	25.	83.33
Nitrate of potash	14.25	10.	——— soda	50.	100.
——— soda	33	100.	——— ammonia	50.	100.

† The most general rule for judging of the *solubility* of a salt is by its taste. Those salts which have the most taste are generally the most soluble in water.

This difference in the solubility of salts is of great use in separating the salts from each other. The refiners of salt petre operate entirely on this principle. Rough petre is always contaminated with a portion of muriate of soda and other salts. In order to separate them they dissolve the whole in water, and by boiling the solution, and evaporating a part of the water, the muriate of soda, &c. falls down, while the salt petre is held in solution. When the greatest part of these salts is thus separated, the remaining liquor is suffered to cool, and the nitrate of potash is obtained in crystals.

Most salts dissolve more copiously in hot than in cold water. Muriate of soda, or sea-salt, is almost the only exception to this general law. Was this a contrivance of Nature in reference to the waters of the ocean, which are enabled to take up nearly as much salt as if they were in a state of ebullition?

‡ Tables of the fusibility of the different salts have not yet been formed; but with the aid of Wedgwood's pyrometer it would be no very difficult task to ascertain the degree of fusibility of each.

The relative fusibility of several of them is already known. For instance; it is known that sulphate of potash requires a much more intense heat to put it in a state of fusion than sulphate of soda, &c. Nitrate and muriate of soda melt as soon as they become red.

What takes place in these decompositions?

When such salts are mixed in solution, the acid of the *first*, having more affinity for the base of the *second* than for its own base, unites itself to it, while the acid of the second combines with the base of the first; so that two new salts are produced, differing in appearance, and possessing properties different to those of the original salts.

What is the cause of these effects?

They are owing to chymical attraction, and are called double decompositions, or decompositions by compound affinities*.

What use is made of these decompositions?

By these means many valuable salts are procured for the use of the chymist and the manufacturer, which can be formed in no other way †.

What knowledge have we attained respecting the native *salts?*

Many of the salts are found native; and since the science of mineralogy has been so much cultivated, great attention has been paid to these natural productions‡.

What salts are furnished by nature in the greatest abundance?

The carbonates, the sulphates and the muriates, are most abundant; but some of the nitrates, borates, &c. are also found native.

Which of the carbonates have been found native?

Of carbonate of lime§ there are immense mountains in most parts of the world; carbonate of barytes has been found in Lancashire and elsewhere; carbonate of Strontian, at Strontian in Scotland; carbonate of soda, in the natron beds of Egypt and in the East Indies; and carbonate of potash has been discovered in spring water.

What sulphuric salts are found native?

Sulphate of soda is found in sea-water, and in salt springs ||;

* Those who wish to investigate this subject may consult Bergman's treatise on "Elective Attractions," or Fourcroy's last System of Chymical Knowledge.

† The following are some of those useful salts which are not found native, but are formd entirely by art;—sulphate of ammonia, nitrate and muriate of barytes, nitrate of ammonia, oxygenized muriate of potash, phosphate of soda, phosphate of ammonia, &c.

‡ Fourcroy is of opinion, that in proportion as fossils are examined, all the salts which art can fabricate will be found native.

§ Carbonate of lime is found also in a crystallized state, called *calcareous spar*. It has never yet been crystallized by art. This process of nature, for aught we know, may require many ages to effect.

|| According to the analysis of M. Lavoisier, the proportion of sulphate of soda in sea-water is very small. Some time ago Mr. Hume analysed the famous Godstone mineral water, and found it to contain 160 grains phate of soda per gallon.

sulphate of magnesia, in spring water*; sulphate of alumine, in abundance at Whitby; sulphate of barytes, in Derbyshire and other parts of the world; sulphate of strontian, in the neighbourhood of Bristol; and sulphate of lime is an abundant mineral in the vicinity of Paris and in several of the counties of England†.

What native MURIATIC salts are there?

Muriate of lime and muriate of magnesia‡ are found in abundance in sea-water; muriate of ammonia appears in the neighbourhood of volcanoes; and muriate of soda not only exists in immense quantities in the ocean§, but vast mountains in dif-

* Sulphate of magnesia and sulphate of lime are both very common in our spring waters; the last salt and supercarbonate of lime are the chief causes of what we call *hard* waters, which are unfit for washing and solution of soap. When soap is used with these waters a double decomposition takes place; the sulphuric acid of the selenite unites with the alkali of the soap and forms sulphate of potash, or sulphate of soda, which remain in solution, while the magnesia or lime unites with the tallow and forms an insoluble compound which swims upon the surface of the water like curds. In this way hard waters require much more soap for any given purpose than rain water, or waters which do not contain these earthy salts. Such waters are also unfit for boiling any esculent vegetable; but they may be rendered soft by adding a little soda or carbonate of lime to them 24 hours previous to their use. Selenite, being a super-sulphate, the superabundant sulphuric acid will combine with the alkali, &c. and the salt, reduced to a common sulphate, will be precipitated.

† Sulphate of lime is gotten in great abundance, at Chelaston near Derby, and at Beacon Hill near Newark. At the former place 800 tons are annually raised; it is sold at 5*s*. per ton on the spot. The price at Gainsbro' is 8*s*. per ton. This mineral is much used in Derbyshire for making the floors of cheese-chambers, store-rooms, granaries, &c. They burn the gypsum, grind it to powder, and then mix it with water. In this state it is laid upon the floors about 2½ inches think, and when dry is a smooth and durable flooring. The whole expence is generally less than 1*s*. 6*d*. per square yard. Gyspsum is also found in most of the cliffs of the Severn, especially at the Old Passage near Bristol. For the London market, perhaps, it might be gotten cheapest from Sheppy Isle, where it may be had in abundance.

‡ The magnesia of commerce is generally procured from this source. It is prepared in large quantities in the island of Guernsey, and elsewhere.

§ In the south of France large trenches are cut near the sea, which fill with sea-water at high tide; the water being confined there by flood-gates, the sun evaporates it and leaves the salt in the trenches, from whence it is laid up to dry for use. Nicholas has published a long memoir on the manufacture of salt, in Ann. de Chimie, tom. xx. 78—188.

The ocean contains from $\frac{1}{23}$th to about $\frac{1}{15}$th of its weight of salt. On account of the cheapness of the fuel at Newcastle, salt is procured there by the evaporation of sea-water. They evaporate 30 or 40 tons of water to procure one ton of salt.

At some places in Cheshire, they draw the brine from the salt pits and saturate it with rock salt previous to their boiling it down. The port of Liverpool is supplied from these wiches, where it is sold for 1*s*. per cwt. for exportation. According to lord Dundonald, 100 tons of a saturated solution of rock salt in sea-water contain 23 tons of salt.

ferent parts of the world are entirely formed of this salt*.

Which of the NITRIC salts are found native?

Nitrate of potash combined with calcareous earth occurs in various places; nitrate of magnesia sometimes appears combined with that salt; and nitrate of lime is found in calcareous stones, and in mineral springs:—these are the only nitric salts that have been seen native in any large quantities.

Are any other of the salts found native?

Yes: vast rocks in Derbyshire and elsewhere are formed of fluate of lime†; borate of soda is found in a crystallized state in the kingdom of Thibet; and phosphate of lime, which is the basis of all animal bones, exists native in Hungary, and composes several entire mountains in Spain.

How do you imagine that these immense masses of salts have been formed by nature?

The vast mountains of salts which occur in various parts of the earth were probably formed in very remote ages, and by processes of which we can form no idea. It may be supposed that some of these processes were slow and gradual, as several of

In Sweden they freeze the sea-water, throw away the ice, and boil down the remainder to salt.

In the landgraviate of Thuringia in Saxony a new method has been adopted in the manufacture of salt. A number of vessels of wood are placed firm upon posts 6 feet from the ground, which may be covered or uncovered in an instant by a moveable roof, accordingly as the weather is dry or rainy. In this manner salt is obtained by the mere heat of the sun, which is much purer than that which is procured by evaporation in boilers. Nicholson's Journal, 4to. vol. ii. 71.

* The salt-mines near Cracow in Poland, which have been worked ever since the middle of the thirteenth century, contain an immense store of this salt. The excavations have been made with so much regularity and beauty, that these mines are visited by travellers as one of the greatest curiosities in the world. Eight hundred workmen are employed in them, who raise 168,000 quintals of salt annually. Through the enormous mass of salt, which presents to the eye no interruption in its saline texture, and at the depth of 450 feet, flows a stream of pure, fresh, and transparent water, which is received in large wooden vessels, where the workmen and horses of these subterranean regions quench their thirst. As it was impossible that this spring could filter through the salt, Nature, which buries her masterpieces in the bowels of the deepest mountains, has placed in this monstrous mass of salt a stratum of clay sufficiently thick to allow this stream of water, destined to refresh the workmen, to pass through it in such a manner as to be protected from the action of the salt, of which a very small quantity would injure its salubrity. See an interesting account of these mines in vol. x. of the Phil. Mag.

† This crystallized substance is used for vases and other ornamental work, some of it being extremely beautiful. It obtained the name of *fluor* spar, on account of its being readily fused. It has also been called *vitreous* spar, because when fused it has the appearance of glass. It is generally found in very regular cubical crystals, and of various colours. See page 157.

the native salts exhibit marks of regularity and beauty in their crystallization which cannot be imitated by art*.

Have geologists attempted to account for the production of the immense quantities *of salts found in different states in various parts of the earth?*

The cause of this order of things can only be referred to the will of the Creator, who has seen fit, in the composition of many of the mountainous parts of the globe, to prefer these compound substances to the simple and inert earths†.

Can you see any advantages arising from this profusion of salts?

The beneficent Creator doubtless foresaw many advantages which would arise from this constitution of things, of which we can have no idea‡. Indeed his bounty appears to have been so

* In order to account for these productions of nature, various *theories* of the world have been formed by philosophers in different periods. Some of these have had many supporters. Thus we have had the theories of Burnet, Woodward, Whiston, Buffon, Whitehurst, La Place, and others.

The theories which divide the opinions of geologists of the present day, are those of Hutton and Werner. The former supposes the agency of fire, and is called the Plutonian system; the latter, which attributes all the present appearances of the globe to the effect of water, is called the Neptunian system. The reader may become acquainted with the arguments which have been adduced in support of both these theories, by means of the following works, which cannot fail to prove extremely interesting to those who are fond of such inquiries: "Playfair's Illustration of the Huttonian Theory of the Earth," 8vo. 1802. And "An Examination of Playfair, by Mr. Murray of Edinburgh."

† We have abundant reason to believe that nothing is fortuitous, but that every thing upon this fair world of ours is the effect of design; for every thing around us bears evident marks of the skill and beneficence of its Omnipotent author. Is it not then reasonable to infer, that the formation of the whole of the globe entered into the Divine plan; and that the constitution of the interior of its mountains resulted from the determination of infinite wisdom, and must have important uses in some future period of the world?

For lives the man whose universal eye
Hath swept at once the unbounded scheme of things;
Mark'd their dependence so, and firm accord,
As with unfaultering accent to conclude
That this availeth nought? THOMSON.

‡ It is probable that the profusion of earthy and akaline salts which occurs in the more elevated parts of the earth may, among other purposes, have been intended as magazines for the future renovation of the soils in their vicinities. They are in general of a nature to be washed down by the rains; and, by means of rivers, &c. are sometimes transported to considerable distances from their native beds. It is remarkable that these salts are generally found only in the *secondary* mountains, the materials of the *primitive* rocks being entirely different. These latter contain no remains of organic bodies whatever, and are composed, for the most part, only of five mixed earths, viz. quartz, alumine, lime, magnesia, and iron; of which *quartz* is by far the most abundant and universal. Though a comparative softness has been given to the secon-

extensive, that the inhabitants of this world can never be in want of any of those substances which are so useful to them in a variety of ways. Should its *latest* inhabitants have occasion for an alkali, or a mineral acid; for an earthy or a metallic salt, they will have only to repair to a mountain or to the ocean for an inexhaustible supply.

dary mountains, which thus appear to have been designed for the successive production of alluvial depositions, &c. the rocks of granite, the pillars of the globe, are so extremely hard, that it is imagined they would resist the constant washing of the ocean for ages without any apparent diminution. Where they were originally fixed by the hand of Nature—

They still remain,
Amid the flux of many thousand years,
That oft has swept the toiling race of men,
And all their laboured monuments away.

THOMSON.

In this arrangement we perceive nothing like a fortuitous concourse of atoms, but, on the contrary, the same satisfactory marks of contrivance, which obtrude themselves upon us whenever we study the phænomena of the world, or behold any of the great operations of Nature.

CHAPTER IX.

OF SIMPLE COMBUSTIBLES.

WHAT is a SIMPLE substance?

Those bodies* which have never yet been decomposed nor formed by art are called simple substances.

* "The most minute particles into which any substance can be divided *similar* to each other, and to the substance of which they are parts, are termed its *integrant* particles; the more minute particles into which bodies can ultimately be divided by *chymical* means are called their *elementary* particles." Dr. Duncan.

How many simple substances are there?

The simple substances at present known amount to 41*; they are called *radicals*.

Can you enumerate the simple substances?

All the simple substances that we are acquainted with are, light, caloric, oxygen, nitrogen, muriatic acid, nine earths, the four simple combustibles, and twenty-three metals†.

Is it well ascertained that these are all simple substances?

It is possible that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it is natural to conceive them to be real simple undecomposeable bodies‡.

Having already examined the nature of all these substances, except the combustibles, we shall now enter upon the consideration of that class of bodies.—Endeavour, therefore, to enumerate the simple COMBUSTIBLES.

Besides the metals§ there are four simple combustibles, viz. hydrogen, sulphur, phosphorus, and carbon.

Suppose a little common salt were reduced to powder, even though it be ground as fine as could be effected by art, still every single particle, however minute, would consist of a particle of soda and a particle of muriatic acid; common salt being a *compound* body incapable of decomposition by mechanical means. But if we take a piece of sulphur, and pulverise that in the same way, every particle will be a homogeneous body, sulphur being one of the *simple* substances.

* If these substances were all capable of combining together, the compounds formed by them would amount to a great many thousands; but many of them are incapable of combining with each other.

† If we omit the earths (and there is some reason to suppose that these are compound bodies) most of the simple substances are combustible, or bear some relation to combustion, either as products or supporters of combustion. Light and caloric are evolved during combustion; oxygen is the principal agent of combustion; and hydrogen, nitrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments, of this process.

‡ It is curious that most of those substances which were thought by the old chymists to be the elements of all other bodies, are found by our improved methods of experiment to be more or less compounded; while of those which were formerly ranked among the class of compounds, there are a great number that are really not decomposeable, and can only be placed among the simple bodies. *Air*, *fire*, *water*, and *earth*, were by the ancients called the elements of the globe: modern chymistry has demonstrated, that the three first of these are really compound bodies; and there is reason to believe that the latter is also a compound. On the other hand, *sulphur*, *phosphorus*, *carbon*, and the *metals*, which we call simple substances, were supposed formerly to be compounds.

§ The metals ought to have been included in this chapter with the other simple combustibles; but as several of their properties are so very different to the four substances now described, it was thought most adviseable to treat of them separately.

Why are these substances called SIMPLE *combustibles?*

Not only because they are simple substances, but it is to distinguish them from a variety of combustible bodies which are compounded of two or more of these simple elements*.

It will be necessary to examine each of these substances separately:—therefore what is the nature† of HYDROGEN?

Hydrogen is the basis of inflammable air‡, and is one of the component parts of water§; but it cannot be exhibited in a separate state. We therefore know it only in combination with other substances, or with caloric in the gaseous form.

* For the nature of the compound combustibles, consult the chapter on Combustion.

† Mr. Cavendish was the first person who examined hydrogen gas and pointed out its nature. Dr. Black then suggested the propriety of applying it to the inflation of air-balloons; but Mr. Cavallo first put it in practice. This gas is about twelve times lighter than atmospheric air.

‡ Like all other combustibles, hydrogen will not burn unless in contact with atmospheric air, or some substance that contains oxygen. If a portion of atmospheric air be mixed with this gas, and fire be applied, it will explode with violence. It is related of Pilatre de Rosier, that having mixed one part of common air with nine parts of hydrogen gas, and drawn the mixture into his lungs, it caught fire by accident as he respired, and the whole of the gas exploded in his mouth and nearly stunned him. The shock was so violent, that at first he thought the whole of his teeth had been driven out, but fortunately he received no injury whatever. Being myself engaged some time ago in a process in which a large quantity of hydrogen gas was evolved, and having incautiously brought a lighted candle too near the apparatus, the whole exploded with a tremendous crash; and several very large glass receivers, shattered into ten thousand pieces, were driven to every part of the laboratory. Such accidents should be noticed in every elementary chymical work, in order to inspire the young pupil with caution when operating on such substances.

§ Hydrogen is the most inflammable substance we are acquainted with; that is, it combines with more oxygen than any other body, and occasions more heat by its combustion. It may be remarked that *oxygen* is mild when in the proportion of 22 per cent. in atmospheric air, and highly corrosive in the proportion of 70 per cent. in nitric acid: How is it, then, that it is found in the ratio of 85 per cent. in water, and that this substance, formed by it, is so perfectly mild and innocent? The infinite Contriver of all good hath endowed *hydrogen* with such an ardent attraction for oxygen, that it unites with a larger portion of it than any other substance, and by its union therewith renders it bland and salubrious. Instances of a similar accommodation of the elementary substances have been adduced; and though we cannot comprehend the nature of their operation, we can perceive that the ultimate end of the Creator is the convenience and the happiness of his creatures. See pages 56 and 132. All other oxidized substances, when taken internally, act perceptibly on the system; yet this, the most oxidized of all others, has comparatively little influence, because its oxygen is so forcibly retained by the hydrogen. Had the affinity of hydrogen for oxygen been as feeble as that of nitrogen and oxygen, what is now the most salubrious beverage would have operated as a corrosive poison.

In what other compounds is hydrogen an ingredient?

Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon.

What is the nature of the compound hydrogen and water?

Water may be made, by pressure, to absorb a considerable portion of hydrogen gas*. It is called hydrogenated water, and is said to be useful in medicine†.

What is the nature of the compound hydrogen and sulphur?

Hydrogen gas when combined with sulphur forms sulphuretted hydrogen gas, which is a very fetid elastic fluid, somewhat heavier than atmospheric air‡.

What are the properties of sulphuretted hydrogen gas?

Sulphuretted hydrogen gas § possesses all the characters of an

Berthollet has shown that there is a greater disposition in hydrogen than in carbon to combine with oxygen, at all temperatures. Chymical Statics, vol. i. 244.

A mixture of oxygen and hydrogen gases produces the most powerful heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each into a common tube connected with both, and throwing a stream of the mixed gases on burning charcoal, or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe and stop-cock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown on the burning substance. In performing this experiment all solid vessels should be discarded for fear of an accident by explosion. When bladders are used no damage can arise, even if such an accident should happen.

* Though hydrogen is insoluble in water, it becomes soluble when combined with sulphur. In this case the hydrogen imparts solubility to the sulphur and the sulphur to the hydrogen; for each, taken separately, is perfectly insoluble in this liquid.

† By pressure, water may be made to absorb near a third of its bulk of this gas. It is said that water, thus impregnated, is useful in inflammatory fevers and other complaints which require similar treatment.

‡ To obtain this gas, melt together in a crucible equal parts of iron filings and sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar being inverted and full of water. Then pour diluted muriatic acid through the mouth of the vessel, which must be immediately closed up. Sulphuretted hydrogen gas will be disengaged in abundance and fill the glass jar. Thomson.

According to Thenard, this gas is composed of 70 parts of sulphur and 30 of hydrogen.

See Berthollet's paper on this gas in the Ann. de Chimie.

Water impregnated with sulphuretted hydrogen gas is of use to separate some metallic oxides when they are in solution. Thus, if it be added to a solution of acetate of lead, the lead will be precipitated of a deep brown colour.

§ This gas was long known by the name of *hepatic* gas, because the substances from which it first obtained were called *hepars*, or *livers of sulphur*.

acid*: it combines with earths, alkalies, and with several of the metallic oxides; and forms with them those substances called *hydrosulphurets.*

What are the properties of the hydrosulphurets?

The hydrosulphurets are soluble in water, and their solutions precipitate the metallic oxides from metallic solutions. Exposure to the air decomposes these hydrosulphurets when dissolved in water†.

What is the nature of the combination of hydrogen and phosphorus?

Hydrogen gas when combined with phosphorus forms *phosphuretted hydrogen gas*‡. This gas has a putrid fetid smell, and takes

When this gas is set on fire in contact with oxygen gas it burns with a pale blue flame without exploding. It will of itself extinguish burning bodies, and destroy animals which are made to inhale it.

Sulphuretted hydrogen gas is decomposed by atmospheric air. The oxygen of the atmosphere combines with the hydrogen and forms water, while the sulphur is precipitated. The sulphur which is found in the neighbourhood of mineral springs originates from this cause.

The fetid smell which arises from house-drains is owing in a great measure to a mixture of this gas with other putrid effluvia. As the diffusion of this noxious matter within our dwellings tends to produce disease and mortality, it cannot be too generally known that a cheap and simple apparatus has been contrived for carrying off the waste water, &c. of sinks, and which at the same time prevents the possibility of any air ever returning back into the house from thence, or from any drain which may be connected with it. It is known by the name of a *stink-trap*, and may be had at some of the ironmongers in London.

* As sulphuretted hydrogen gas is formed without oxygen, it seems to overthrow the doctrine of Lavoisier, who asserted that oxygen was the only principle of acidity.

† The waters of Harrowgate and Aix la Chapelle owe their medicinal properties to sulphuretted hydrogen gas and muriate of soda. The *salt of bitumen* of the Hindoos, which is almost the only article of Hindoo physic, and is sold in every village, is chiefly composed of muriate of soda and sulphuretted hydrogen. It is taken by these people for every complaint. Their farriers give it to the horses, and seem to understand the principle on which it acts; for when they have given a dose to the animal they always give him water to extricate the gas. Henderson on Hindoo Physic.

Secret correspondence has often been carried on by means of Harrowgate water. A letter written with a solution of acetate of lead is illegible; but if it be dipped in this water, the writing will appear, and shortly become almost black. Hydrogen has the property of reviving metallic oxides; hence ladies who have used metallic cosmetics, have become dark tawneys by bathing in these waters.

‡ This gas is formed by introducing phosphorus into a glass jar full of hydrogen gas standing over mercury, and melting the phosphorus by means of a burning glass. It burns with great rapidity in common air, but in oxygen gas the combustion is extremely brilliant. If bubbles of this gas be made to pass up through water, they explode in succession as they reach the surface of the liquid, and a beautiful coronet of white smoke is formed, which rises slowly to the ceiling of the room. This gas is the most combustible substance known. Thomson, vol. i. 66.

fire whenever it comes in contact with atmospheric air *.

What is the nature of the combination of hydrogen with carbon?

Hydrogen gas, when combined with carbon, forms what is called *carburetted hydrogen gas*, or heavy inflammable air †.

The facility with which phosphuretted hydrogen gas inflames is no doubt owing to the phosphorus being so minutely divided by the hydrogen.

Mr. Davy forms this gas by decomposing water with zinc and sulphuric acid, and adding to the mixture small pieces of phosphorus. But as some management is necessary in order to conduct the process successfully, I refer the reader to his paper in Nicholson's Journal for April 1802.

According to Dr. Skrimshire, phosphurretted hydrogen gas may be formed by boiling a little phosphorus in a solution of pure potash. The water is decomposed thereby, and furnishes the hydrogen. The retort should be nearly filled with the solution, otherwise the gas will inflame.

* If bits of phosphorus are kept for some hours in hydrogen gas, *phosphorized hydrogen* gas is produced, having somewhat of the smell of garlic. If bubbles of it are thrown up into oxygen gas, a brilliant blueish flame will immediately pervade the whole vessel. This slow combustion is owing to the gas containing *less phosphorus* than the *phosphuretted hydrogen* gas. It is this gas which is often seen hovering on the surface of burial grounds, known by the name of *will-o-the-wisp.*

† This gas is formed at the bottom of stagnant waters in hot weather, and may be readily collected at their surface by suspending a bottle of water over the pool, stirring up the mud, and suffering the carburetted hydrogen gas to ascend into it, similar to the decanting of gases over a pneumatic trough.

Such gas generally contains a portion of carbonic acid gas mixed with it. These gases are produced in stagnant pools by the decomposition of water. The putrid animal and vegetable matter decomposes the water and combines with its oxygen, while the hydrogen is liberated in the form of gas. The carbonic acid gas which rises with it is produced by the union of oxygen with the carbon of these putrifying matters. These decompositions only take place when the sun shines upon the waters, as caloric is necessary to give these substances a gaseous state.

It may be formed artificially by exposing charcoal in glass vessels filled with hydrogen gas to the rays of the sun.

It is invisible, elastic, and inflammable. The proportions of carbon and hydrogen vary according to the process by which the gas is obtained. Dr. Thomson.

This gas is procured from pit-coal by dry distillation for the purpose of forming the thermo lamp, and might be applied very economically for light-houses on the sea-coast, or for lighting mines and large manufactories. See page xxii. A pound of coal will produce about 24 gallons of this inflammable gas.

Hydrogen and carbon also form all the oils; and, with the addition of oxygen, resin, wax, sugar, and gum. Hydrogen likewise enters as a constituent part into the composition of all the animal and vegetable acids, and is one of the bases of ammonia and of some of the compound gases.

An oil may be formed artificially by the following process: Place a glass tube on the shelf of a pneumatic trough, send up into it three parts of fresh prepared carburetted hydrogen gas, and add to it gradually four parts of fresh prepared oxygenized muriatic acid gas. After each addition of the gas, shake the mixture; an absorption will take place, caloric will be liberated, and the tube will become filled with white vapours.

What is the origin of SULPHUR?

Sulphur is found in most parts of the world* combined with metals, from which it is procured by roasting: it also flows from volcanoes; it is sublimed from the sulphureous grounds in Italy, and is found in many mineral waters.

What is the nature of sulphur?

Sulphur, or brimstone as it is sometimes called, is a solid, opaque, combustible† substance, of a pale yellow colour, insoluble in water, very brittle, and with little taste or smell. Its specific gravity is 1.990, or nearly twice as heavy as water. It has various uses in medicine and the arts‡.

What compounds are formed by means of sulphur?

Sulphur combines with oxygen, hydrogen, nitrogen, the alkalies, the metals, some of the earths, phosphorus, &c.

What are the compounds of sulphur and oxygen?

If sulphur be kept in fusion in atmospheric air it absorbs a small quantity of oxygen, and forms oxide of sulphur§; if it be heated sufficiently to take fire, it burns with a pale blue flame, and becomes converted to *sulphurous* acid; but if sulphur be

When the gases have totally disappeared, an oil of an agreeable odour will be deposited, which will become yellow by exposure to the air. This is a process of the Dutch chymists for preparing olefiant gas.

* Sulphur is so plentifully diffused, that probably it was known very early: according to Pliny, it was used in his time in medicine, and for bleaching wool.

Sulphur is procured in large quantities from martial pyrites and other metallic ores. It is also found in abundance in the state of native sulphur, as it is called, near several volcanoes, in different parts of the world. According to Dr. Anderson there are mines of it in the kingdom of Thibet. The Bee, vol. xvii. 25. In the Isle of Anglesea it is sublimed from the copper ore, and collected in large chambers which are connected with the kilns by means of long horizontal flues. A particular account of the process may be seen in Mr. Arthur Aikin's Tour through North Wales. See also Henkel's Pyritologia.

† Sulphur during its combustion combines with oxygen, and becomes an incombustible substance. Like phosphorus, it is eminently combustible, owing to its great affinity for oxygen. See page 126.

It is well known, that if sulphur be kept melted in an open vessel, it at length becomes thick; but I believe it has not been noticed by any writer on chymistry—that it has the peculiar property of becoming *thinner* as it cools, till it becomes nearly as thin as water.

‡ Sulphur is used in large quantities for making gunpowder. It is also very serviceable in medicine, as it has the property of penetrating to the extremities of the minutest vessels, and of impregnating all the secretions; as is found by those who have taken it for any length of time. Sulphur has many uses in the arts, and has been employed with advantage in stopping the progress of fermentation of wines and other fermented liquors.

§ See the chapter on Oxides; also Fourcroy's System of Chymical Knowledge, vol. i. 276.

burned in oxygen gas, the combustion is very rapid, and *sulphuric* acid is the product*.

What are the compounds of sulphur and the alkalies?

Sulphur will combine with potash, with soda, and with ammonia; which compounds possess several curious and interesting properties.

What are the general characteristics of the alkaline sulphurets?

They are hard substances, of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and emit a fetid odour, similar to that of rotten eggs. They have the property of decomposing water, and by that process become partially converted to alkaline sulphates†.

What knowledge have we acquired of the combinations of sulphur with the earths and metals?

Sulphur may be combined artificially with most of the metals‡, and with some earths; but many of the metallic sulphurets are found native in great abundance.

What is the origin of phosphorus?

Phosphorus is a peculiar substance of animal origin. It was formerly obtained from urine by a long and tedious process; but is now procured by the decomposition of the phosphoric acid which is found in bones§.

* For an account of the changes which take place in sulphur when it becomes oxygenized, see page 126.

† The sulphurets can only exist in a state of desiccation, or at least can contain but a very small portion of water without the water being decomposed.

‡ There are only two metals, gold and zinc, which refuse this combination. Some of the metallic sulphurets have much colour, and are employed as pigments.

Sulphuret of lime is recommended by Mr. Higgins as a cheap substitute for potash in bleaching. For the method of preparing it consult his work on the Theory and Practice of Bleaching, published in Ireland, in 1799.

§ Phosphorus was discovered accidentally at Hamburg in 1669 by an alchymist of the name of Brandt; and two years afterwards one Kraft brought a small piece of this substance to London on purpose to show it to the king and queen of England. Mr. Boyle afterwards discovered the process, which he described in the Phil. Trans. for 1680. Mr. Boyle instructed Mr. Godfrey Hankwitz of London how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years.

The writer of this has in his possession a scarce portrait, by Vertue, of this chymist in the midst of his laboratory, surrounded by his chymical apparatus; the form of which shows that even at that time they had the means of accurate analysis, if they had had a rational theory to direct them. From a Latin inscription it appears that he had this print engraved to present to his customers on his taking leave of them, when about to enter upon his travels abroad to sell phosphorus.

The discovery of phosphorus proves that valuable discoveries may be made by men who have no means of appreciating their nature. Even Stahl maintained that it was the *marine salt* contained in urine which yielded phosphorus.

What is the nature of phosphorus ?*

Phosphorus is a solid inflammable† substance, which has the peculiar property of appearing luminous in the dark‡. Its specific gravity is rather more than twice that of water. By combustion it is converted to an acid§.

What compounds are formed by means of phosphorus ?

Phosphorus combines with oxygen, with hydrogen, with nitrogen, with sulphur, with most of the metals||, and with some earths¶.

* Phosphorus when taken internally is poisonous. It is related in the Annales de Chimie that a great number of domestic fowls and turkeys were poisoned merely by drinking the water in which some newly made phosphorus had been washed. Though poisonous, it has been given in *small* quantities by some French physicians, in malignant fevers, to stop the progress of gangrene, in which it succeeded beyond all hope. Nicholson's Journal, vol. iii. 85.

† If a piece of phosphorus be placed on the surface of water a little below the heat of boiling, it will immediately inflame. This is one characteristic of phosphorus; and distinguishes it from all other substances.

‡ Phoshorus is used in forming phosphoric acid in various chymical experiments, and in making phosphoric match bottles. These bottles may be prepared by mixing one part of flour sulphur with eight of phosphorus. When used, a small quantity is taken out of the bottle on the point of a match, and rubbed upon cork or wood, which produces a light immediately.

Phosphorus is employed in making phosphoric ether, phosphoric oil, phosphoric tapers, phosphuret of lime, and various phosphoric fire-works. The methods of forming these combinations may be seen in Bouillon La Grange, and other authors.

§ Phosphorus, surrounded by cotton rubbed in powdered rosin, and placed under the receiver of an air-pump, takes fire after exhaustion, and displays very beautiful phænomena on the gradual admission of the air.
Van Marum.—Parkinson.

According to Fourcroy, phosphorus undergoes no change in oxygen gas unless heat be applied, and then it burns with great splendour. It is not even luminous in oxygen gas, or in nitrogen gas, though it be so much so in atmospheric air. Gren's Chymistry.

|| Phosphorus will combine with all the metals except gold and zinc. Berthollet. It unites with iron, and forms that kind of iron called *cold-short*. Iron of such property acquired this name on account of its being very brittle when cold, though malleable when heated. Such iron may be made good and fit for most purposes by heating it with carbonate of lime. Ann. de Chim. tom. xlii. 832.

¶ Some animals have very peculiar phosphorescent qualities. The light of the glow-worm is well known, but the *pyrosoma atlanticum* has not been described by naturalists. M. Peron, on his voyage from Europe to the Isle of France, observed this animal between 3 and 4 degrees north latitude. Its phosphorescent quality, so truly prodigious, renders it one of the most beautiful of zoophites known; and its organization ranks it amongst the most singular. When it was first discovered the darkness was intense, the wind blew with violence, and the progress of the vessel was rapid. All at once there appeared, at some distance, as it were a vast sheet of phosphorus floating on the waves; and it occupied a great space before the vessel
vessel soon passed through this inflamed part of the sea; and they

What is the nature of these compounds?

With oxygen, phosphorous forms an oxide of phosphorus, also the phosphorous and the phosphoric acids*; with hydrogen, phosphuretted hydrogen gas†; with nitrogen, phosphuretted nitrogen gas; with sulphur, phosphuret of sulphur, and sulphuret of phosphorus; with the metals, metallic phosphurets‡; and with some of the earths, earthy phosphurets.

What is the origin of carbon?

Carbon in a state of purity is known only in the diamond; but it may be procured in combination with oxygen by burning wood in a covered crucible.

What compounds are formed by means of carbon?

Carbon combines with oxygen, with hydrogen, with nitrogen, with sulphur, with phosphorus and with iron.

What is the nature of these compounds?

Carbon with various doses of oxygen forms charcoal, carbonic oxide§, or carbonic acid ||; with hydrogen and caloric, carburetted hydrogen gas¶; with nitrogen and caloric, carburretted nitrogen gas; with sulphur, carburretted sulphur; with phosphorus, phosphuretted carbon; and with iron, plumbago, or carburet of iron**.

Some of these compounds having been already examined, it will now be expedient to consider the other combinations of carbon;—therefore what is charcoal?

Charcoal is burnt wood, or the coaly residuum which is left after burning any vegetable in close vessels††.

that this prodigious light was occasioned entirely by an immense number of small animals, which swam at different depths, and appeared to assume various forms. Those which were deepest looked like great red-hot cannon balls; whilst those on the surface resembled cylinders of red-hot iron. Some of them were soon caught, and were found to vary in size from three to seven inches. All the *exterior* surface of the animal was bristled with thick oblong tubercles, shining like so many diamonds; and these seemed to be the principal seat of its wonderful phosphorescence. In the inside also there appeared a multitude of litle oblong narrow glands, which possessed the phosphoric virtue in a high degree. The colour of these animals, when in repose, is of an opal yellow mixed with green; but on the slightest movement of those spontaneous contractions which it exercises, or those which the observer can at pleasure cause by the least irritation, the animal inflames, and becomes instantly like red-hot iron, and of a most brilliant brightness. As it losses its phosphorescence it passes through a number of tints successively, which are extremely agreeable, light, and varied, such as red, aurora, orange, green, and azure blue: this last shade is particularly lively and pure. A further account of this curious creature may be seen in the Journal de Physique.

* See the nature of these acids in the chapter on Acids.

† See page 173. ‡ See page 177.

§ See the chapter on Oxides for an account of these combinations.

|| See page 135. ¶ See page 174. ** See page 186.

†† Charcoal for common purposes is made by a less expensive process. The wood is disposed in heaps regularly arranged, and covered with earth, so as

What are the characters and appearances of charcoal?

Charcoal is generally black, sonorous and brittle, very light, and destitute of taste or smell*.

What are the properties of charcoal?

Charcoal is a powerful antiseptic†; has a great affinity for oxygen‡; is unalterable and indestructible by age§; and not affected by the most intense heat, if air and moisture be excluded.

to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up till all the water and oil are driven off; after which the fire is extinguished by shutting up all the air-holes.

Lavoisier's Elements, 279.

* Charcoal is so porous that it may be seen through with a microscope; and however large the piece, it may be readily blown through. According to Dr. Bancroft, charcoal is a vegetable oxide, and, like manganese, owes its black colour to its union with oxygen. He also considers the indestructibility of charcoal to be owing to its absorption of oxygen; in which state it will resist the combined action of sun, air, moisture, &c. for hundreds of years. See Philosophy of Permanent Colours, 48.

† "All sorts of glass vessels and other utensils may be purified from long retained smells of every kind, in the easiest and most perfect manner, by rinsing them out well with charcoal powder, after the grosser impurities have been scoured off with sand and potash. Rubbing the teeth and washing out the mouth with fine charcoal powder will render the teeth beautifully white, and the breath perfectly sweet, where an offensive breath has been owing to a scorbutic disposition of the gums. Putrid water is immediately deprived of its offensive smell by charcoal." Crell's Journal, vol. ii. 170.

Meat, which is only a little tainted with putridity, may at once be made sweet by charcoal: if common raw spirits be agitated with charcoal, they will be deprived of their bad flavour.

‡ Owing to its affinity with oxygen, charcoal will decompose the sulphuric and nitric acids. It decomposes the latter with great rapidity. If the charcoal be dry and finely powdered, and the acid *strong*, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire-work.

§ "The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years, the charcoal has remained as entire as if it had been formed but yesterday, and it will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most ancient times; the famous temple at Ephesus was built upon wooden piles, which had been charred on the outside to preserve them." Watson's Essays, vol. iii. 48.

"It is said that there still exists charcoal made of corn in the days of Cæsar, which is in so complete a state, that the wheat may be distinguished from the rye." Willich.

"About forty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent the passage of Julius Cæsar and his army. They were *charred* to a considerable depth, retained their form completely, and were firm at the heart." Dr. Robison. The ancients wrote with levigated charcoal, the most indestructible substance we know; and accordingly, the writings found in Herculaneum are still a perfect bla

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To what uses is charcoal applied?

Charcoal is used in large quantities in making gunpowder; it is employed as an antiseptic in purifying rancid oils, &c. in decomposing the sulphuric acid; and for many other purposes, by the chymist and the manufacturer*.

Is charcoal a simple or a compound substance?

Charcoal is a compound substance; it is an *oxide* of carbon, or the woody fibre partially oxidized; it also contains hydrogen†, and a portion of fixed alkaline salt and earth; but these are rather adventitious than essential ingredients.

What is carbon?

Carbon is the base of charcoal, divested of all impurities.

What is the most striking property of carbon?

Carbon is capable of crystallization, in which state it forms the diamond‡.

Casks charred in the inside are now used to preserve water in sea voyages; and such casks are found to preserve the water uncorrupted. Dr. Black, vol. ii. 285.

* Charcoal is used by mathematical instrument-makers and engravers to polish their brass and copper plates. Plates of horn and lanthorn leaves are polished with it. It is also much used by artists in tracing the outlines of drawings.

† Charcoal always contains hydrogen, which it retains after the most powerful calcination. It is this want of hydrogen which renders the diamond much less combustible than charcoal.

‡ The diamond is pure carbon, entirely divested of oxygen; charcoal contains 64 parts diamond and 36 oxygen in every 100; carbonic acid has 28 parts charcoal and 72 of oxgen, or 18 diamond and 82 oxygen. The diamond is chiefly found in the kingdom of Golconda in Asia, and in Brazil. It always occurs crystallized; indeed, if not, it would be carbon and not diamond. See a note respecting the diamond under the article Steel, in the chapter on Metals; where you have an additional proof that diamond is simple carbon. It is wonderful that Newton, who had no chymical means of examining the diamond, should have concluded that it contained a large portion of inflammable matter. See Additional Notes, No. xxix.

Mr Tennant has shown satisfactorily, that the diamond is pure carbon, carbon crystallized. See Phil. Trans. for 1797. The diamond is one of the hardest substances in nature, and one of its rarest productions. From its hardness it is employed for sawing and boring the hardest stones. "Diamonds are usually found in an ochreous yellow earth, under rocks of gritstone; they are likewise found detached in torrents, which have carried them from their beds. They are seldom found above a certain size. The sovereigns of India reserve the largest, in order that the price of this article may not fall. Diamonds have no brilliancy when dug out of the earth, but are covered with an earthy crust." Fourcroy. Diamonds are also found in considerable numbers in the island of Borneo. Whenever the mines are searched for them, an overseer attends and watches the workmen with great care, that the largest may be secured for the sovereign prince. Notwithstanding they are frequently conveyed away clandestinely by the workmen swallowing them. Von Wurmb's History of Borneo.

A minute account of the diamond mines of Brazil may be seen in Ann. de Chim. tom. xv. 82; and in Nicholson's Journal, 4to. vol. i. 24.

What other properties has carbon?

Carbon has the property of de-oxidizing the oxides of metals and other combustible substances*, and of uniting with their oxygen and forming carbonic acid†.

Does carbon enter into any other combinations?

Carbon is found in large proportions in bitumen and pit-coal‡; it seems to be ready formed also in vegetables; and enters into most animal and some mineral substances§.

What is the proportion of carbon in pit-coal?

Pit-coals vary in quality, according to the different proportions of carbon and bitumen which they contain‖; but carbon is the

The usual method of calculating the value of diamonds, is by squaring the number of carats, and then multiplying the amount by the price of a single carat; thus, supposing one carat to be worth 2*l*. a diamond of 8 carats is worth 128*l*. being 8 X 8 X 2. A carat is 4 grains. *Polished* diamonds, without blemish, are worth about 6*l*. per carat.

* Charcoal has a very strong affinity with oxygen; it takes oxygen from almost every other substance.

† The merit of the discovery of the carbonic acid is due to the illustrious Dr. Black of Edinburgh. Those who have not been in the habit of reading the early chymical writers, can have no idea of the service which this great man has rendered the science by his very accurate investigation of this substance.

‡ There are good reasons for supposing that bitumens and pit-coal have been formed in the bed of the sea by the decomposition and deposition of animal matters. The quantity of volatile alkali which these substances yield on distillation favours this opinion. An interesting paper by Mr. Kirwan on the proportions of carbon in the different kinds of coal, will be found in Nicholson's Journal, 4to. vol. i. 487.

See an ingenious paper by Mr. Hatchett on the origin of bitumen, &c. in the Phil. Trans. for 1804.

An interesting account of the springs of fossil tar near Shrewsbury, and at Colebrook Dale, may be seen in Archdeacon Plymley's View of the Agriculture of Shropshire.

§ Charcoal has the property of forming an intimate union with the fixed alkalies, if fused with them.

Plumbago contains a small quantity of oxygen: it is therefore an oxide of the first degree; charcoal, an oxide of the second; carbonic oxide, of the third; and carbonic acid, the product of the complete oxidizement of carbon.

‖ The immense quantity of pit-coal which is deposited beneath the surface of the earth is truly astonishing, and affords abundant matter for reflection. This kind of fuel is consuming day after day in incalculable quantities; and so great is the store which has been laid up for our use, that there is no probability of its being exhausted for ages yet to come. Supposing the formation of pit-coal to be owing to the deposition of marine animal matter; the same process must be still going on, and the inmost recesses of the present seas may be receiving the materials of fuel for the inhabitants of new continents in the most remote periods of the world. The wise economy of the great Author of Nature, in this constant circulation of the elements of matter, is equalled by nothing but his own infinite beneficence.

chief ingredient in all. What are called *slaty* coals contain also from 10 to 40 per cent. of earth*.

What is the use of carbon in the vegetable kingdom?

Carbon is not only a component part, but forms nearly the whole of the solid basis of all vegetables, from the flower of the garden to the oak of the forest†.

If carbon forms so large a part of all vegetables, what occasions that infinite variety which we observe in the vegetable creation?

We are in a great measure strangers to the economy of vegetables; but much of this variety may be attributed to the different proportions of carbon in the materials of which they are composed‡.

* There are four species of coal, very distinct from each other. The *graphite* of Werner, or plumbago; the *anthracolite*; the *jet*, or canal coal and the common coal.

One hundred parts of *plumbago* contain 90 charcoal and 10 iron. The best quality, which is found at Keswick in Northumberland, is used in making pencils.

Anthracolite, or coal blend, is distinguished from other coal by burning without flame. It is composed of 64 charcoal, 33 silex, and 3 parts of other earths.

Jet is composed of bitumen and charcoal: 75 parts charcoal, 22 parts bitumen, and 2 parts earth.

Common coal is composed of bitumen and charcoal in different proportions, according to its quality and the places whence it is procured.

† It has been discovered that air which has been spoiled by the breathing of animals is peculiarly fitted for the vegetation of plants; No doubt this is owing to its containing a larger portion of carbonic acid than is found in common air.

By the analysis of soils it has been proved, that of all the substances found in the mixture of earths which constitute a soil, calcareous earth contributes most certainly to its fertilization. This probably proceeds from the carbonic acid. An interesting account of some experiments on manures, by Mr. Arthur Young, on a small scale, may be seen in the Retrospect, vol. i. 118.

Vegetables have the power of absorbing oxygen from the atmosphere, and of transmitting it to the absorbent vessels of the roots. It cannot be questioned but that this oxygen becomes useful in vegetation, by converting the carbon of manures into carbonic acid. Fourcroy, vol. viii.

The operation of *paring* and *burning* turf, which is always found by farmers extremely serviceable to their lands, is doubtless rendered universally advantageous from the carbonaceous matter which is produced by the burning.

‡ When we consider the small number of simple substances which enter into the composition of plants, how astonishing is the variety that has been afforded us by the bounty of nature! The species of vegetables already known are more than 40,000, and large additions are daily making to this number by new discoveries. Is it possible that so bountiful a provision can have been made by nature ultimately for the use of man?—Yes; "for him she has covered the earth with plants; and though their species be infinite in number, there is not one but may be converted to his use. She has selected some out of every class to minister to his pleasures, or his support, wherever he shall please to fix his habitation. Others serve for his bed, for his roof,

What products of vegetation are there which are indebted to carbon for their formation?

Carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins, of which there are many varieties.

How are these substances formed by the vegetating organs of plants?

All living vegetables have the power of decomposing water*, and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic † acid of the atmosphere ‡, to form these vegetable products.

If carbon and hydrogen enter into the composition of all these substances, how is it that one vegetable affords gum, another resin, another oil, &c.§?

The infinite variety which there must be in the internal

for his clothing, for the cure of his diseases, and for the fire of his hearth." St. Pierre.

Fourcroy has remarked "that vegetables may be considered as beings intended by nature to *begin* the organization of crude matter, and to dispose the primitive materials of the earth and atmosphere in order to become the source of life, and consequently to establish a communication between minerals and animals; from whence it follows, that plants are truly chymical apparatus employed by nature to produce combinations which would not take place without them." Nature is as admirable in the smplicity of her means, as in the constancy and regularity of her operations.

* When we decompose water, we can do it only by abstracting its oxygen by combustible substances, and liberating the hydrogen. Vegetables effect this in a different way; they preserve the hydrogen, and set the oxygen free. This process of Nature, in the latter instance, has been noticed in a former chapter.

Berthollet has remarked, that the decomposition of water must always take place to give rise to substances of a resinous character, when the vegetation is performed without the concurrence of foreign bodies. Chymical Statics, vol. ii. 393.

† Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth, covered carefully with sheet lead; he kept it in this state for five years, watering it with distilled water; and at the end of that time the tree weighed 169 pounds, three ounces; the earth in which it had vegetated being weighed at the same time, was found to have lost only three ounces. This was repeated by Mr. Boyle with a similar result. Dr. Skrimshire's Essays on Natural History.

‡ Senebier found, that plants watered by water, impregnated with fixed air, grew more luxuriantly than plants watered as usual, and that when insulated from every substance which could afford it to them immediately, they acquired carbon by the decomposition of carbonic acid gas in the atmosphere. Berthollet.

It appears from hence that *solid* matter is not necessary to the growth of vegetables; and that they owe their increase chiefly to the decomposition of water and carbonic acid.

§ Carbon and hydrogen are not the only principles which enter into composition of all these substances. Most of them contain a propor of oxygen also, as may be seen by the following statement:

organization of vegetables, to enable different orders to prepare such different substances from the same elements, renders this subject too intricate and minute for our investigation. We feel the insufficiency of our faculties—"The will of God is the ultimatum of all human knowledge."

Is it known what other substances are employed by nature for the formation and growth of vegetables?

All orders of vegetables are produced from four or five natural substances, viz. caloric, light, water, air, and carbon*.

*

Olive oil		
Carbon	79	
Hydrogen	21	
	100	

Sugar	
Carbon	28
Hydrogen	8
Oxygen	64
	100

Resin	
Carbon and Hydrogen proportions unknown.	Saturated with oxygen.

Wax		
Carbon	82	Saturated with oxygen.
Hydrogen	18	
	100	

Gum	
Carbon	23
Hydrogen	11
Oxygen	65
Nitrogen & lime	1
	100

The formation of resin and wax has lately been explained thus: That when a volatile or a fixed oil is expelled out of the plants, and has its surface exposed to the air, the first becomes a resin by losing hydrogen, the second a wax by absorbing oxygen.

* It has been shown that water and atmospheric air are the natural food of plants. Caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon. Some plants yield also a portion of silex, and others lime; but these no doubt are taken up by the roots from the soil.

When we consider that the many thousand tribes of vegetables are not only all formed from a few simple substances, but that all enjoy the *same* sun, vegetate in the same medium, and are supplied with the *same* nutriment, we cannot but be struck with the rich œconomy of Nature, and are almost induced to doubt the evidence of those senses with which the God of Nature has furnished us. That it should be possible so to modify and intermingle a few simple substances, and thereby produce all the variety of form, colour, odour, &c. which is observable in the different families of vegetables, is a phenomenon too astonishing for our comprehension. Nothing short of Omnipotence could have provided such a paradise for man.

"Soft roll your incense, herbs, and fruits, and flowers,
In mingled clouds to Him, whose sun exalts,
Whose breath perfumes you, and whose pencil paints."

THOMSON.

How is it that those few substances can produce the variety of forms, colours, tints, odours, tastes, qualities, &c. observable in this kingdom of Nature?

The means by which all this is effected are unknown to us; but this we know, that "these wonderful harmonies are not in the nature of the elements, but in the will of Him who has ordained them, in subordination to the wants of his numerous creatures*."

What is the office of carbon in the animal *kingdom?*

As carbon is a necessary part of sugar, oils, fat, &c. it consequently enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gelatine, fibrina, and animal urine.

Does carbon enter into any mineral combinations?

It is imagined that most of the metals may be combined with carbon; but at present we are acquainted only with combinations with iron and zinc†.

What does carbon form when combined with iron?

In one proportion it forms cast iron ‡; in another steel; and in a third proportion plumbago, hitherto improperly called black lead§.

* The various orders of vegetables which have been provided for the countless forms of animated existence, in the different quarters of the globe, are eminently illustrative of the provident care of the Creator, and show us how great and how good is the Father of the families of the whole earth. The following passage from St. Pierre is so well calculated to impress this truth, that it is unnecessary to apologize for its introduction: "The sluggish cow pastures in the cavity of the valley; the bounding sheep on the declivity of the hill; the scrambling goat browses among the shrubs of the rock; the duck feeds on the water plants of the river; the hen, with attentive eye, picks up every grain that is scattered and lost in the field; the pigeon, of rapid wing, collects a similar tribute from the refuse of the grove; and the frugal bee turns to account even the small dust on the flower. There is no corner of the earth where the whole vegetable crop may not be reaped. Those plants which are rejected by one are a delicacy to another, and even among the finny tribes contribute to their fatness. The hog devours the horse-tail and hen-bane; the goat the thistle and hemlock. All return in the evening to the habitation of man, with murmurs, with bleatings, with cries of joy, bringing back to him the delicious tribute of innumerable plants, transformed, by a process the most inconceivable, into honey, milk, butter, eggs, and cream."

† We have reason to believe that carbon unites with metals only by fusion; and that the different kinds of carburetted metals which are found, have all undergone intense heats at some period of the world.

‡ Cast iron acquires carbon during its fusion in the smelting furnaces.

Metals which contain but little carbon are called carburetted *metals*; on the other hand, plumbago and such other metallic substances as are composed with more carbon than metal, are denominated metallic *carburets*.

§ The name which this substance has so long borne shows how necessary it was to give a new nomenclature to the science. It is now known, that

What is the proportion of carbon in cast iron?

Upon an average cast iron contains, according to the analysis of Bergman, about one forty-fifth of its weight of carbon*.

What quantity of carbon enters into the composition of steel?

Steel is iron combined with about one part of carbon in two hundred of iron†.

How is carbon combined with iron to form plumbago?

Carburet of iron, or plumbago‡, has been found to consist of nearly nine parts carbon to one of iron.

What is the nature of the combination of carbon with zinc?

Carbon combines largely with zinc; but the nature of this combination is not much known.

You said that carbon formed an acid by its union with oxygen: how is that effected§?

what has been called black *lead* owes its metallic quality to *iron*; and that there is no portion of lead in its composition. Many other instances might be adduced, in which the names of substances have given false ideas of their nature and properties.

* Cast iron does not owe its brittle qualities to the carbon which is combined with it; for that iron which contains most carbon is found to be the best metal. Cast iron generally contains a portion of phosphate of iron, and always a quantity of oxygen: these substances give it its hard brittle quality. To convert cast iron into wrought iron the metal is submitted to a long intense heat, by which means the carbon burns, and uniting with the oxygen, both go off in the state of carbonic acid gas. The iron is then carried to the forge hammer, which beats out the phosphate or phosphuret of iron, and brings the particles closer together. When the iron is required to be pure and good, it undergoes repeated hammering till it is brought to the desired quality.

† To procure steel, nothing more is necessary than to heat good pure iron for several hours in a proper furnace, with charcoal, or any substances proper for furnishing a sufficient quantity of carbon, which is absorbed by the iron in the process. Iron has so great an affinity for carbon, that it is even capable of decomposing the carbonic acid in a high temperature. See Philosophical Magazine, vol. ii. where there is an account of a late mode of making steel by fusing soft iron in crucibles, with carbonate of lime.

‡ Plumbago is found in great plenty at a place called Burrow dale, in Cumberland. Its chief use is in making pencils, called black lead pencils. It is likewise useful to rub over wooden machinery, where there is much friction.

Carburet of iron is found also on various parts of the continent. It often occurs in mountains, in the midst of beds of quartz, or calcareous earth. It has lately been found crystallized in octahedrons.

Plumbago (like charcoal) is indestructible by heat, unless with the presence of atmospheric air. It is therefore much used for making crucibles and portable furnaces. It protects iron from rust, and on that account is rubbed on various ornamental cast iron works, such as the fronts of grates, &c.

§ The pupil may be satisfied of the composition of carbonic acid by the following experiment: Take one of those glass receivers which are generally used for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having a piece of ignited cortical part of charcoal ready, suspend it by a wire to the stopper of the receiver, and immerse

Carbon has so great an affinity to oxygen, that when assisted by heat it will take it from most substances with which it may be combined; they then form carbonic acid gas*.

What quantity of oxygen is necessary to convert carbon into carbonic acid?

Twenty-eight parts by weight of carbon require 72 parts of oxygen to saturate them; so that 100 parts of carbonic acid are composed of twenty-eight parts of carbon, and seventy-two parts of oxygen†.

What is the specific gravity of carbonic acid?

Carbonic acid can only be exhibited in the form of gas; each cubical inch weighs near three quarters of a grain.

What are the properties of the carbonic acid gas?

it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful corruscations. When the inflammation is over the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid.

* There can be no doubt that carbonic acid is formed by the union of carbon with oxygen; for steel may be made as effectually by the decomposition of carbonic acid, as it can by the direct union of iron with carbonaceous matter.

Carbon takes a gaseous form also by combining with hydrogen and caloric, and forms what is called carburetted hydrogen gas. Likewise the gas discovered by Dr. Priestley, and which Mr. Cruickshank named the *gaseous oxide of carbon.*

† Oxygen has a greater affinity for carbon than for any other substance. Mr. Lavoisier burned small quantities of charcoal in pure oxygen gas in close vessels, and found that a part of this gas was converted into fixed air. He séparated this from the rest of the oxygen by means of caustic alkali, and weighed the alkali after it had attracted the fixed air. He also expelled the air again by an acid, and examined its bulk. Thus he learned the weight of the air, and what measure of it had been produced. Then, comparing this weight with that lost by the charcoal which had been consumed, he found it to exceed greatly the weight of the charcoal, and was exactly equal to the weight of the charcoal added to that portion of the oxygen gas which had been changed into fixed air. Dr. Black.

The composition of carbonic acid has been further proved by analysis, as it has actually been decomposed, and the charcoal exhibited entire. See Mr. Tennant's Experiments on fixed Air, in Phil. Trans. vol. lxxxi. 181. When a diamond is burnt the proportions are different to the above, for it is the purest carbon we are acquainted with. It requires to form 100 parts of carbonic acid, only 17.88 of diamond, and 82.12 of oxygen. In burning diamond, carbonic acid is the product, and there is *no* residue. One part of charcoal absorbs 2.527 of oxygen, and produces 3.575 of carbonic acid; whereas one part of diamond absorbs more than four parts of oxygen, and produces five of carbonic acid.

Carbonic acid gas may be readily procured for experiment by pouring a little diluted sulphuric acid into a phial, or a retort, upon a little pulverized chalk. An action will immediately commence; and if one end of a bent tube be made fast in the neck of the phial, and the other brought under the mouth of a jar filled with water, and inverted in a vessel of the gas will pass from the mixture into the inverted jar.

Carbonic acid gas is invisible and elastic, is twice as heavy as atmospheric air*, will mix with vital air, may be combined with water, to which it gives a brisk and acidulous taste†, and will occasion the death of animals that are obliged to breathe it‡.

In what states does carbonic acid exist in Nature?

Carbonic acid is found formed by Nature in three different states, viz. in gas, in mixture, and in chymical combination; it is perhaps the most abundant of all native acids§.

What instances are there of its natural existence in the state of gas?

It is found in the proportion of one per cent.‖ in atmospheric air; also in caverns and mines, where it is called the choke damp¶.

* Owing to its density this gas may be poured from one vessel to another like water, or may be drawn from a cask by a cock like other fluids. In consequence of its great specific gravity this gas is frequently found at the bottom of mines, wells, &c.

† In order to saturate water with this gas it is necessary to subject it to a considerable degree of pressure. The persons who are engaged in making the acidulous soda water have peculiar conveniences for this purpose. Cyder, perry, bottled beer, and other fermented liquors, owe their briskness and sparkling to the presence of this gas.

‡ Carbonic acid has also the property of rendering lime soluble in water. As the carbonic acid escapes by exposure to the air, the calcareous matter is precipitated from the water which held it in solution; whence arise the various earthy incrustations found in different parts of the world. Fourcroy has very aptly remarked, that "when natural history was less enlightened by chymistry, springs of this kind were called *petrifying* waters, and were by the vulgar reckoned among the number of miracles."

§ Plants of all kinds give out carbonic acid gas while growing in the shade; but when assisted by the rays of the sun, there is reason to think that the plants have the power of decomposing this acid; for then the leaves give out only oxygen gas. Annales de Chimie, tom. xiii. p. 318.

‖ The use of this gas in atmospheric air is not accurately known. Perhaps the large quantity of carbonic acid, which is perpetually forming by the processes of respiration and combustion, seizes the putrid exhalations which arise from the earth, and preserves the atmosphere from being contaminated with them. We know that *carbon* has the property of uniting chymically with putrid miasmata, and rendering them innoxious. It seems likely then that one per cent. of carbonic acid gas is diffused throughout the atmosphere, in order that it may be ready to arrest every malignant vapour at the moment of its formation by the putrefactive process. Without some such contrivance we should be in perpetual danger of pestilential contagion.

How *vast* is the tribute I owe
Of gratitude, homage, and praise,
To the Giver of all I possess,
The *life* and the *length* of my days! JERVIS.

¶ The floor of the Grotto del Cane, in Italy, is lower than the door, and this hollow is always filled with fixed air, which can rise no higher than the threshold of the door, but flows out like water. If a dog go in he is im-

What instances are there of carbonic acid being found mixed with fluids?

It is found abundant in Spa-water, and in some other acidulous waters*.

In what substances is carbonic acid found chymically combined?

Carbonic acid is found in all parts of the world in great plenty, in combination with the alkalies, in earths, and in stones; particularly in chalk, limestone, and marble†.

mersed in the fixed air, and dies immediately: but a man enters with safety, because his mouth is far above the surface of the deleterious air. From the loss of so many dogs in this cavern it acquired the name of the Grotto del Cane. Dr. Black, vol. ii. 94. The lake of Averno, which Virgil supposed to be the entrance to the infernal regions, evolves so large a quantity of this gas, that birds flying over it drop with suffocation. Fatal accidents have happened to persons who have incautiously descended into brewers' vats before they have been purified from this gas.

This gas so often occupies the bottoms of wells, that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter with safety; if not, a quantity of *quick lime* should be let down in buckets, and gradually sprinkled with water. As the lime slacks it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

Fatal accidents often happen from burning charcoal in chambers; whenever charcoal is burnt this gas is formed. Workmen have also lost their lives by sleeping too near limekilns, where this gas is extricated in abundance. Whenever persons are discovered in such situations, or are suffering from the effects of carbonic acid gas, the same means should be made use of as are directed by the Humane Society in cases of apparent death from drowning: or, when it can be done without loss of time, atmospheric air, or even pure oxygen gas, should be forced into the lungs.

Carbonic acid has been given medicinally with success, and has proved a powerful antiseptic. Meat which has been sealed up in it has been known to have preserved its texture and appearance for more than twenty years.

* These waters have a pleasant light acidity and briskness, and sparkle in the glass like fermented liquors; which is well known to be the case with water which is artificially impregnated with fixed air. Dr. Black says, that carbonic acid gas "is grateful to the stomach, and has a most agreeable, refreshing, and cooling taste, when applied there." Dr. Percival esteems it highly medicinal in pulmonic consumptions, and in malignant fevers.

A description of a proper apparatus for impregnating water with this gas will be found in Bouillon la Grange's Chymistry, vol. i. 93.

† Carbonic acid is found combined with alkalies and with several metallic oxides. These combinations are called carbonates.

"It would be a valuable discovery to society, if we could decompose this gas by any cheap process, as by such means we might obtain, for economical purposes, the immense store of charcoal contained in calcareous earths, marbles, limestones," &c. Lavoisier's Elements.

"The immense quantity of carbonic acid which exists in the many provinces of limestone, if it was extracted and decomposed, would afford charcoal enough for fuel for ages." Darwin's Botanic Garden.

A cubic inch of marble contains as much carbonic acid in combination as would fill a six-gallon vessel when in the state of gas. Dr. Black's Ltures.

What is the effect *of the combination of carbonic acid?*

Carbonic acid renders mild and salutary some of the most acrid and destructive substances we are acquainted with*.

How is the carbonic acid separated from alkalies and earths?

Carbonic acid may be disengaged by all the other acids, but it is usually separated from alkalies by the addition of quick lime, which absorbs this acid, and thereby becomes converted into carbonate of lime†.

How is carbonic acid usually procured for chymical purposes?

Carbonic acid gas may be collected in abundance from the surface of fermenting liquors; but it is more commonly obtained by pouring sulphuric acid upon a mixture of carbonate of lime (common chalk), and water‡.

How do you account for the production of carbonic acid gas in the process of fermentation?

In all vinous fermentations a decomposition of the saccharine matter takes place; and a part of the disengaged oxygen, uniting with a part of the carbon of the sugar, forms carbonic acid. A decomposition also of part of the water of solution perhaps promotes the process.

What is the cause of vinous fermentation?

The cause of vinous fermentation is not well understood; but it appears to be a spontaneous commotion that takes place on

Marble contains of carbonic acid	407 parts in 1000.
Crystals of soda	423 parts ditto.
Mild volatile alkali . . .	533 parts ditto.
Carbonate of magnesia . .	594 parts ditto.

* The causticity of pure quick lime every one is acquainted with; and the corrosive qualities of the fixed alkalies are well known: but when these substances are *fully* saturated with carbonic acid, the first forms mild calcareous earth, (or chalk) and the others mild neutral salts, applicable to many purposes of medicine and domestic economy.

† Though the alkalies readily part with their carbonic acid to caustic calcareous earth, yet they have a great affinity to this acid, as may be shown by the following interesting experiment: Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potash, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its surface will be seen covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

‡ It has been matter of surprise to me that no advantage has been taken of the vast quantities of carbonic acid gas which are perpetually escaping from the vats of the large breweries in this metropolis. It might surely be collected, and applied to many useful purposes. The benefit which is derived from *yeast* in putrid diseases, is due to its carbonic acid. An interesting paper on the use of this remedy may be seen in the sixth volume of the Philosophical Magazine, 56.

the decomposition of vegetable substances, in certain favourable circumstances of temperature and solution, and is a process which Nature employs for their destruction*.

What circumstances are necessary to produce vinous fermentation?

The presence of vegetable matters, of water, of sugar†, a certain degree of heat‡, and free access of atmospheric air.

Can you at all account for the change which is effected in saccharine liquors by fermentation?

By the process of fermentation the sugar, which is a vegetable oxide§, parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol by being thus partially deoxidized.

Does sugar then become spirit of wine, or alcohol, merely by losing a part of its oxygen?

No: it parts with a portion of its carbon at the same time, in the form of carbonic acid gas, and the remainder forms alcohol‖.

* It is now pretty generally known that no substances are capable of fermentation but such as have been elaborated by the principle of animal or vegetable life. See a memoir on this subject by Fourcroy, part iii. chap. 22.

Fourcroy admits five distinct species of vegetable fermentations, viz. the saccharine, or that which forms sugar, the vinous, the acetous, the colouring, and the putrid. See Fourcroy's System of Chymical Knowledge, vol. viii. 148.

† It appears from several late experiments carefully made, that sugar is composed entirely of hydrogen, oxygen, and carbon. Mr. Cruickshank made many experiments on fermentation, and invariably found, that whenever he added a fourth substance to the three which compose saccharine matter, no fermentation took place. He tried lime, and at another time a small quantity of potash; and the addition of either prevented fermentation. See Mr. John Thomson's Notes to Fourcroy, vol. iii. 128; also Dr. Rollo on Diabetes.

‡ To produce vinous fermentation, it is necessary that the matters subjected to that process should be placed in a temperature not lower than 55 degrees of Fahrenheit. No kind of fermentation is ever known below the freezing point.

§ Lavoisier having analysed sugar, found that it was composed of hydrogen, oxygen, and carbon, in the following proportions: Hydrogen 8lbs. oxygen 64lbs. carbon 28lbs. in every 100 pounds weight of sugar. Lavoisier's Elements, 188. Having subjected 100lbs. of sugar to fermentation, he found the products (viz. alcohol, carbonic acid, and acetous acid), when analysed, contain the precise quantities of hydrogen, oxygen, and carbon, which were contained in the original sugar. The particular detail which he has given of these experiments is extremely interesting. Ibid. p. 185 to 197. In consequence of the results which were obtained, he remarks. "The effect of the vinous fermentation upon sugar is thus reduced to the mere separation of its elements into two portions: one part is oxygenized at the expense of the other, so as to form carbonic acid; while the other part, being disoxygenized in favour of the former, is converted into the combustible substance called alcohol." Ibid. p. 196.

‖ The spiritous quality of all fermented liquors is owing to the they contain, whether it be malt liquor, wine, or spirits.

Endeavour to recollect the different properties of charcoal which you have enumerated in this chapter.

Charcoal appears to be indestructible by age; it is not in the least altered by the most intense heat, if heated in *closed* vessels; when burnt in atmospheric air it becomes converted into carbonic acid gas; it is a valuable antiseptic; it is the basis of all vegetables; and one of the component parts of wax, oils, gums, and resins: from its affinity to oxygen it has the property of decomposing the sulphuric and nitric acids, and of reducing them to first principles; it will decompose all the sulphuric salts; will reduce all the metallic oxides to a metallic state; and, combined with ozygen in the form of gas, has the property of rendering the most acrid and caustic substances in nature mild and innocent: and lastly, its pure carbonaceous matter is capable of crystallizing in the form of diamond*; but this latter has never been effected by art.

How did chymists become acquainted with all these properties of charcoal?

Formerly, nothing was known of charcoal but its indestructibility and its antiseptic qualities. The other peculiar and surprising properties of charcoal were reserved for the discoveries of the present age; for which discoveries we are indebted to the labours and genius of Black†, Priestley‡, Cavendish, Lavoisier, Guyton, Tennant, and Berthollet; and to the gradual development of the present improved system of chymistry.

What reflections naturally present themselves on the consideration of the various properties of charcoal and the other simple combustibles?

This subject, when considered in all its connections, is calculated to produce the most profound admiration; and serves to convince us of the unbounded comprehension of that Divine

* See Additional Notes, No. xxxvi.

† In the year 1755 Dr. Black discovered the acid gas which is thrown off from fermented liquors and from mild calcareous earth. He called it *fixed air*.

‡ Dr. Priestley explained the effect of charcoal in decomposing nitrous acid, examined the gas that is thrown off in this decomposition, and pointed out the necessity of distinguishing the different gases from common air; for which the Royal Society awarded him an honorary prize.

In the years 1766 and 1767 Mr. Cavendish published papers in the Philosophical Transactions on the nature of elastic fluids, in which he announced that he had produced fixed air by the burning of charcoal. This assurance called the attention of all chymists to that surprising substance, and was the forerunner of the many discoveries which have since been made respecting its properties, &c.

Lavoisier pointed out the nature of the action of charcoal in reducing metallic oxides; investigated the nature of the combustion of the diamond; announced the exact quantity of carbon in carbonic acid; and the production of carbonic acid by the decomposition of water with ignited charcoal.

mind, which, in the act of creation, could foresee and appoint such important effects to result from the combinations and changes of the most inodorous and insipid substances. We learn also, that all the works of the Creator are perfect; and perceive with astonishment, that they are composed of elements which are in themselves incapable of destruction*.

* See Additional Notes, No. xxv. and xxxvii.

CHAPTER X.

OF METALS.

WHAT are the characteristics of the metals?

The general characters of metals are, great specific gravity*, lustre, opacity, fusibility, malleability, and ductility; but some metals are neither malleable nor ductile.

How are the metals procured?

They are generally taken from the bowels of the earth†, in a state of combination either with other metals‡, with sulphur,

* Metallic substances have a much greater specific gravity than all other bodies. A cubic foot of marble weighs only 252 pounds; whereas a cubic foot of tin, the lightest metal, weighs 516 pounds, and a cubic foot of gold weighs 1326 pounds.

† Metals are generally found in mountainous countries, in such as form a continued chain; but the metallic part of a mountain usually bears but a small proportion to its whole contents. Granite rocks seldom contain any metallic ores.

It is deserving of notice, that if minerals had been placed on the *surface* of the globe, they would have occupied the greatest part of the earth, and would have prevented its cultivation. Their being deposited *below* is a proof of management and design worthy the divine architect.

‡ When metals are found combined with other metals they are called native alloys.

oxygen, or with acids*, though a few of them have occasionally been found in a state of purity†.

By what methods are the metals purified from these substances?

The metals are purified from their ores by various means; such as washing, roasting, fusion‡, &c.; but the method must always be regulated by the nature of the ore to be assayed§.

How many metals are there?

There are twenty-three distinct metals, which possess properties very different and distinct from each other||.

How are the metals classed by modern chymists?

They are divided into two classes. The one contains the malleable, the other the brittle, metals. This last class is sometimes

A table of the orders and the genera of the ores of metals may be seen in Dr. Thomson's Chymistry, vol. iv. 19.

* The sulphuric, muriatic, phosphoric, and carbonic acids are those which are generally found in combination with metals.

† Among those metals which most frequently occur in the *metallic* state may be ranked quicksilver. In Bishop Watson's Chymical Essays mention is made of such a mine in this country, viz. at Berwick in Northumberland, in the midst of that town; and Mr. Hume, a friend of mine, a native of that place, assures me he was an eye witness to this fact.

‡ The analysis of metallic ores in the great, is always performed by fire, and is called the *dry* way; but the more accurate analysis is effected by means of various chymical re-agents which modern chymistry has applied to that purpose, and is termed the *moist* way. Before the time of Bergman every kind of analysis of minerals was conducted by fire: he was the first chymist who resorted to the method of solution in acids, which is easy, simple, and effectual.

§ Those who wish to invsetigate this subject may find ample information in Schlutter's work on Mineralogy; in Henkel's Pyritologia; in Cramer on Metals; and in Kirwan's Mineralogy. Some general ideas on the subject may be collected from a well-written paper of Dr. Thomson's, in his System of Chymistry, vol. iv. 174.

|| For a knowledge of most of the metals, we are indebted to the more perfect modes of analysis which modern chymistry has afforded. The ancients were acquainted with only seven of these metals. The properties of these were tolerably well known to the early chymists, who acquired their knowledge from the alchymists. These infatuated people tortured silver, mercury, copper, iron, tin, and lead, in every way they could devise, in order to convert them into gold. Alchemy was probably introduced into Europe by the crusaders, whose minds were prepared for the reception of any delusion. In all likelihood they picked up the idea of the transmutation of metals on their return from Palestine; and as error generally operates more powerfully than truth with such fanatics, they deluged their native country with these absurdities. The vain and conceited Paracelsus, a Swiss physician, was one of the last of the alchemists. He announced to the world that he had discovered a medicine, which would render man immortal: but worn out by his debaucheries and excesses, he gave the lie to this assertion; for he himself died in the year 1534, at the age of 41.

In the reign of Henry IV. an act was passed to make it felony to transmute metals. This act was repealed in consequence of the suggestions of Mr. Boyle.

subdivided into two others, viz. those which are easily, and those which are difficultly, fused.

How many malleable metals are there?

Ten; viz.

1. Gold,*	6. Iron,
2. Platina,	7. Tin,
3. Silver,	8. Lead,
4. Mercury,	9. Nickel,
5. Copper,	10. Zinc.

How many brittle metals are there?

There are thirteen metals in this class which are neither malleable nor ductile. Indeed few of them can be brought into fusion without an intense heat†.

Which are the easily fusible of the brittle metals?

There are four fusible brittle metals; viz.

1. Bismuth,	3. Tellurium,
2. Antimony,	4. Arsenic.

Which are the brittle metals that are fused with difficulty?

There are nine of these metals; viz.

1. Cobalt,	4. Molybdenum,	7. Chromium,
2. Manganese,	5. Uranium,	8. Columbium,
3. Tungsten,	6. Titanium,	9. Tantalium.

It will be necessary to consider each of these metals separately; therefore, what is the nature *of gold?*

Gold is the heaviest of all the metals, except platina; it is not very elastic, nor very hard; but it is so malleable and ductile, that it may be drawn into very fine wire, or beaten out into leaves thin enough to be carried away by the slightest wind‡.

* Of these metals, the three first have been called noble or perfect metals; because they stand the most intense heat of our furnaces without suffering oxidizement, or any diminution in their weights.

† Owing to the brittle nature of these metals, such of them as were formerly known were called *semi-metals*; but this distinction, as it conveys erroneous ideas, is now generally laid aside.

‡ Dr. Black has calculated, that it would take fourteen millions of films of gold, such as is on some fine gilt wire, to make up the thickness of one inch; whereas 14 million leaves of common printing paper make up near 3-4 of a mile. Vol. ii. 654. According to Fourcroy, the ductility of gold is such, that an ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long. Fourcroy, ii. 495.

Such is the tenacity of gold, that a wire 1-10th of an inch in diameter will support a weight of 500 pounds without breaking.

Gold melts at 32° of Wedgwood. By means of a powerful lens it may be volatilized.

Gold becomes much harder by an union with a small quantity of copper.

Gold leaf, thrown into oxygenized muriatic acid gas, takes fire and with great brilliancy.

Fulminating gold is made by diluting a saturated solution of gol hree times its measure of distilled water, and precipitating the oxide by

Where is gold found?

Gold is found in Peru and other parts of the world. It always occurs in a metallic state, and most commonly in the form of grains.*

What is the effect of oxygen *upon gold?*

Gold has so little affinity for oxygen, that it cannot be oxidized like the other metals; though this may be effected by amalgamating it with mercury, and applying heat†.

aqua ammonia *gradually* added to the solution. The precipitate, when dried on a filter, forms this fulminating powder, which detonates by heat.

Gold may be known from all other metals by its bright yellow colour, and its weight. Its specific gravity is 193; when heavier it must be combined with platina; when lighter, and of a deep yellow colour, it is alloyed with copper; if of a pale colour, with silver.

Gold may be detected when in solution, by green sulphate of iron; this precipitates it of a brown colour, which soon changes to the colour of gold.

* Gold frequently occurs in the ores of other metals, but it is chiefly found in the warmer regions of the earth. It abounds in the sands of many African rivers, in South America, and in India. Several of the rivers in France contain gold in their sands. It has also been discovered in Hungary, Sweden, Norway, and Ireland. Near Pamplona, in South America, single labourers have collected upwards of 200*l.* worth of wash gold in a day. In the province of Sonora the Spaniards found a plain fourteen leagues in extent, in which they found wash-gold at the depth of only 16 inches: the grains were of such a size that some of them weighed 72 ounces, and in such quantities, that in a short time, with a few labourers, they collected 1000 marks (equal in value to 31,219*l.* 10*s.* sterling) even without taking time to wash the earth that had been dug. They found one grain which weighed 132 ounces. This is deposited in the Royal Cabinet at Madrid, and is worth 500*l.* Dr. Black, ii. 694.

The native gold found in Ireland was in grains, from the smallest size up to between two and three ounces. Only two grains were known to have been found of greater weight, one of which weighed five, and the other 22 ounces. See Phil. Trans. for 1796.

Some of the French chymists assert that they have absolutely discovered gold in the ashes of vegetables.

† Gold is susceptible of two degrees of oxidizement; the purple, and the yellow oxide; but neither of them is ever found native.

According to Fourcroy, gold and silver may be oxidized by triturating them in a mortar with saliva. This method is frequently made use of for oxidizing mercury. Saliva has a great affinity for oxygen. Nature seems to have endowed it with this property, that it may absorb oxygen from the air to impart it to the food.

"If gold and silver should, when heated with other metals, undergo a slight degree of calcination by such a process, a stronger heat alone makes them immediately resume their pure and metallic form. The allusion therefore to this quality of the precious metals, to illustrate the triumph of a good heart over misfortune, is peculiarly beautiful; and as this is to be found in the book of Job, the discovery of the oxidizement and reduction of these metals must be very ancient." Dr. Black.

The attraction of gold and silver for oxygen is so slight, that the rays of the sun alone will de-oxidize the oxides of these metals.

The oxides of gold may be reduced by hydrogen gas, or sulphurous acid gas. If satin ribbon, or silk, be moistened with a diluted solution of

What salts *of gold are there?*

There is only one salt of this metal that is much known to chymists, viz. *muriate of gold**, which is obtained in small crystals, and is very soluble in water. Many other salts may be formed with this metal, but nothing at present is known either of their properties, or uses†.

What are the uses *of gold?*

Gold is used for jewellery, for plate, and for current coin; but for these purposes it is generally alloyed‡. Gold is also used to spread over other metals to preserve them from tarnishing or rusting, as gold does not become oxidized by exposure to atmospheric air§.

gold, and while moist, exposed to a current of either of these gases, the metal will be immediately reduced, and the silk become gilt with a regular coat of gold. In this way any ornamental figures may be laid upon silk, the gilding of which will be very permanent. For the rationale of this process consult "Mrs. Fulhame on Combustion," to whom we are indebted for the invention.

* This salt is formed by dissolving gold in nitro-muriatic acid, and leaving the solution at rest for the salt to crystallize. In this process the nitric acid affords oxygen to the metal; and as the metal becomes oxidized the oxide is dissolved by the muriatic acid. Nitro-muriatic acid and oxygenized muriatic acid are the only acid solvents of this metal.

A solution of muriate of gold, when concentrated by evaporation, yields beautiful yellow crystals not unlike *topazes*.

If ether be added to a solution of muriate of gold, the gold will leave the acid, and float upon its surface, combined with the ether. This ethereal solution has lately been used by Mr. Stodart and Mr. Savigny for defending their lancets and other surgical instruments from injury by a damp atmosphere. It was formerly used in medicine under the name of *potable gold.* In those days of credulity it was generally prescribed to all patients who could furnish the apothecary with gold enough to make a sufficient quantity of the medicine to insure a cure. The account which old Glauber gives of this celebrated panacea at the end of his "Treatise on *Philosophical Furnaces*," 1651, page 393, will afford the reader some entertainment.

† As there are thirty-two acids, each of which is probably capable of uniting with each of the metals, the number of metallic salts that may be formed by art will amount to many hundreds: but in this elementary work only those most known will be noticed; particularly the native salts, as these are the most interesting, and will be most easily remembered. In order to form this part of the chapter, I shall avail myself chiefly of Dr. Thomson's account of these bodies.

‡ Gold is generally alloyed with copper. What is called pale gold is alloyed with silver. See an interesting paper on the various alloys of gold, by Charles Hatchett, esq. in Phil. Trans. vol. xciii. 43.

Standard gold of Great Britain is twenty two parts pure gold, and two parts copper; it is therefore called gold of "twenty two carats fine."

§ Gold is also used in a state of solution, for staining ivory and ornamental feathers. It gives a beautiful purple red, which cannot be effaced: even marble may be stained with it. The nitro muriatic acid is the menstruum used for this purpose. The potters dissolve gold in this way, to be applied to the common kind of porcelain. Bismuth or zinc will precipitate gold from this solution. Tin will precipitate it of a beautiful purple, called the *purple*

What is the origin *of silver?*

Silver is found in various parts of the world in a metallic state; also in the states of a sulphuret, a salt, and an oxide*.

What is the nature *of silver?*

Silver is a heavy†, sonorous, brilliant, white metal; exceedingly ductile, and of great malleability and tenacity. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper‡; or drawn out into wire as fine as a hair, without breaking§.

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precipitate of Cassius. This also is used by the potters in printing on porcelain. Sulphuret of potash will dissolve gold completely. Some have thought that Moses made use of this process to render the calf of gold, adored by the Israelites, soluble in water. Stahl wrote a long dissertation in order to prove that this was the case. See Additional Notes, No. xxix.

* Native silver is found chiefly in the mines of Potosi. Sulphuret of silver occurs in the silver mines of Germany, Hungary, Saxony, and Siberia. Oxides of silver are common in some of the German silver mines. Silver has lately been found in a copper mine in Cornwall. See Mr. Hitchen's paper in Philosophical Transactions, vol. xci. 159. Most of our lead mines also afford it.

By the silver which was procured from the lead mines in Cardiganshire, sir Hugh Middleton is said to have cleared two thousand pounds a month, and that this enabled him to undertake the great work of bringing the New River from Ware to London. In 1637, a mint was established at Aberystwith for coining Welch silver. Bishop Watson.

Aristotle says, that some shepherds discovered the method of working the silver mines of Spain; for, having occasion to clear a quantity of land by burning down the wood, they found fused silver produced by the operation of the fires.

It is owing to the spirit which the promulgation of chymical science has diffused among the landholders, that a silver mine has been discovered in Cornwall, which has been worked for 20 years past with advantage.

> Nature, profusely good, with wealth o'erflows,
> And still is pregnant, tho' she still bestows.
>
> BLACKLOCK.

It may be ascertained whether an ore contains silver, by pulverizing it and dissolving it in nitric acid, and afterwards adding a little muriatic acid. Should it contain any silver, the muriatic acid will instantly combine with the whole of it, and precipitate it from the nitric solution in white flakes of muriate of silver. In order to know the proportion of silver in any given quantity of ore, collect this precipitate on a filter, heat it red, and weigh it accurately. Every 100 grains of this precipitate contains 73 grains of pure silver.

† The specific gravity of silver is 10.500. It is a very soft metal.

‡ Fifty square inches of silver leaf weigh not more than a grain.

§ The silver wire used by astronomers is not more than half as thick as a fine human hair.

Silver melts at 28° of Wedgwood. In a temperature much higher it becomes volatilized.

Silver, gold and platina require the heat of a powerful burning lens in order to put them in a state of combustion.

What is the effect of oxygen *upon silver?*

Silver cannot be oxidized by atmospheric air, unless exposed to an intense heat; but the oxide of silver may be procured by dissolving the metal in an acid*, and then precipitating it by a pure alkali. There are two oxides of silver, viz. the gray, and the white oxide†.

What salts *are there of silver?*

The nitrate of silver‡ is best known; but in analysis the sulphate of silver is also a most useful test; and many other salts of this metal may be formed§. The muriate and the carbonate of silver are both found native||.

Silver has a great affinity for muriatic acid: hence muriatic acid is employed as a test for discovering silver in solution.

To know when silver is pure, heat it in a common fire, or in the flame of a candle: If it be alloyed, it will become tarnished; but if it be pure silver, it will remain perfectly white.

* The nitric is the proper acid to dissolve silver. Silver is dissolved in this acid for forming the metallic tree. It is a pleasing experiment attended with very little expense. A metallic crystallization somewhat similar may be made by suspending a piece of zinc in a solution of acetate of lead. See Gren's Chym. vol. ii. 382. Thomson's Fourcroy, vol. ii. 487.

† Metals can combine only with one certain portion of oxygen. If that portion of oxygen be not present, the metal will not become oxidized. Where a metal is susceptible of two degrees of oxidizement, it becomes first oxidized with the smaller quantity of oxygen: after this, the new combination has a further attraction for oxygen, and the second degree of oxidizement takes place.

Silver, when reduced to a liquid amalgam with mercury, is liable to be oxidized at the temperature of the atmosphere. This is owing to its having lost its natural coherence by that operation. The same may be said of an amalgam of gold. Berthollet.

‡ This salt is kept in chymical laboratories as a test for the muriatic acid. When melted and run in moulds it forms the lunar caustic of the apothecary. When dissolved in water and left at rest, it crystallizes in brilliant transparent plates of different forms. Though the solution is as pale as pure water, it will stain the skin and other animal substances of an indelible black. It is employed to dye human hair; for staining marbles and jaspers; and for silvering ornamental work. This salt is the most powerful antiseptic known. One ounce of it dissolved in 12,000 ounces of water will preserve the water from putrefaction for ever, and it may any time be separated therefrom in a few minutes, by adding a small lump of common salt. Dr. Black, vol. ii. 661. An ingenious method of silvering ivory by the solution of this salt may be seen in Count Rumford's Phil. Papers, vol. i. 22.

A solution of nitrate of silver mixed with a little gum water forms the *indelible ink* used in marking linen.

§ Hyperoxygenized muriate of silver has been used in making fulminating powder. If this salt be mixed with half its weight of sulphur, and struck slightly, it detonates with prodigious violence. The flash is white and vivid, and the silver is reduced. Dr. Thomson, ii. 539.

|| Muriate of silver has been found crystallized in Saxony, and in South America. Carbonate of silver has been found in masses in Suabia.

What are the uses *of silver?*

Silver is used chiefly for ornamental work, for domestic* utensils, and for current coin; but for these purposes it is generally alloyed with copper†; without which it would not have sufficient hardness to stand much wear‡.

How is platina *procured?*

Platina is found in grains, in a metallic state, at St. Domingo, and at Santa Fé in Peru§.

What is the nature *of platina?*

Platina is the heaviest of all the metals‖; is nearly as white as silver; and is difficultly fusible; but by great labour it may be rendered malleable, so as to be wrought into utensils like other metals¶. It will resist the strongest heat of our fires without

* Pliny observes, that such was the luxury of the Romans, that it was then simply reckoned a piece of elegance to consume in the ornaments of coaches, and in the trappings of horses, metals which their ancestors could not use in drinking-vessels, without being astonished at their own prodigality. Nero and his wife shod their favourite horses with gold and silver. Watson, vol. iv. 188.

† Our standard silver is formed with 15 parts pure silver, and one part copper.

‡ Silver is used also for plating other metals, for silvering dial-plates, &c. An account of these different processes may be found in Imison's School of Arts.

§ Charles Wood was the first person who brought any of this metal to England He brought it from Jamaica, in the year 1741; and published an account of his experiments upon it, in the Phil. Trans. for 1749 and 1750. Platina in the language of Peru means *little silver*.

The ore of platina contains no less than nine different substances; viz. silex, iron, lead, copper, platina, and five new metals. The properties of these new metals have as yet been but little investigated. For the methods of analysing the ore of platina, consult Dr. Wollaston's and Mr. Tennant's papers in the Philosophical Transactions, which are the best treatises on this metal.

Platina may be distinguished from all other metals by adding a solution of muriate of ammonia to a solution of the metal in nitro-muriatic acid, when a red coloured precipitate will instantly appear. This is the only means yet known to discover when gold has been alloyed with this metal. Gold is generally known, if weighed hydrostatically, by its specific gravity; but if it be alloyed with platina some other test is necessary, as platina has a greater specific gravity than gold.

Some of the methods which have been employed to procure platina in a state of purity may be seen in Thomson's Chymistry, Phil. Trans., and other modern publications.

‖ The specific gravity of hammered platina is 23.00, which is more than double that of lead. It may always be known from other metals by this superior specific gravity.

¶ Mr. Knight was one of the first of the modern chymists who pointed out a way to render this metal malleable. See his paper in Philosophical Magazine, vol. vi. 1. Another method to accomplish this end has been published by Mr. Tilloch in the twenty-first volume of that work.

Platina has been drawn into wire less than the two thousandth part of an inch in diameter.

melting*; and, like iron, is capable of being welded when properly heated.

What is the effect of oxygen *on platina?*

The oxygen in atmospheric air has no effect upon platina†, unless when assisted by an intense heat; but the oxide may be procured by dissolving the metal in nitro-muriatic acid, and precipitating it by an alkali‡.

What salts *are there of platina?*

A variety of salts may be formed with the oxide of this metal; but none of them have yet been brought into any use§. No salt of platina has yet been found native.

What are the uses *of platina?*

Platina has hitherto been chiefly used for chymical utensils, such as crucibles, spoons, &c.||, and to make specula for telescopes. It has also been beaten into leaves, and applied to porcelain in the manner of leaf gold¶. Its oxide is used in enamel painting.

Where is mercury *found?*

Mercury is brought to Europe from the East Indies, and from

* The strongest of the pure mineral acids have no effect upon this metal; neither has the strongest fire, unless it be urged by a stream of oxygen gas. It may, however, be melted by a burning lens, or dissolved in oxygenized muriatic acid, or nitro-muriatic acid. If mixed with arsenic, and then exposed to a great heat, it fuses readily.

† On account of this property, as well as its hardness, it has been recommended for the fabrication of national standard weights.

‡ This metal may be also oxidized by the electric spark, or by heating it with nitre. Native oxide of platina is not known.

Proust says, that when platina is combined with other metals it oxidizes more easily than has hitherto been believed. Annales de Chimie, tome xxxviii.

§ In order to form any salt with this metal, the platina must be previously dissolved in nitro-muriatic acid or oxygenized muriatic acid, these being the only acids that will act upon it. A solution of any other salt is then to be added, and by double affinity the new salt required may be obtained. Thus a solution of phosphate of soda would probably give a phosphate of platina.

|| The important uses to which this precious metal may be applied may be easily conceived when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. Fourcroy, vol. ii. 527.

¶ A very neat method to cover other metals with platina was lately discovered by Mr. Stodart, who found that, like gold, it may be taken up from its solution by sulphuric ether. See Nicholson's Journal for the year 1805.

It is said that M. Strauss has, after many experiments, succeeded in applying platina to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, will render this a most valuable discovery.

An alloy of copper with this metal is likely to prove very valuable, as it is malleable and ductile, is susceptible of a fine polish, and receives no tarnish of its lustre by exposure to the air.

Peru*; but it is found in greater abundance at Almaden†, in Spain, where it is extracted from the ore by distillation‡.

What is the nature *of mercury?*

Mercury, in the temperature of our atmosphere, is a fluid metal§, having the appearance of melted silver; in this state it is neither ductile nor malleable; very volatile when heat-

* The quicksilver mine of Guanca Velica, in Peru, is 170 fathoms in circumference, and 480 deep. In this profound abyss are seen streets, squares, and a chapel, where religious mysteries on all festivals are celebrated. Millions of flambeaux are continually burning to enlighten it. The mine generally affects with convulsions those who work in it. The unfortunate victims of an insatiable avarice are crowded all together, and plunged *naked* into these abysses. Tyranny has invented this refinement in cruelty, to render it impossible for any thing to escape its restless vigilance.

> For in the dark Peruvian mine confin'd,
> Lost to the cheerful commerce of mankind,
> The groaning captive wastes his life away,
> For ever exil'd from the realms of day;
> While, all forlorn and sad, he pines in vain
> For scenes he never shall possess again.
>
> FALCONER.

† In the year 1717, there remained above 1200 tons of quicksilver in the magazines at Almaden, after the necessary quantity had been exported to Peru for the use of the silver mines there.

The quicksilver mines of Idria, a town in the circle of Lower Austria, have been constantly wrought for 300 years, and are thought upon an average to yield above 100 tons of quicksilver annually. Watson.

‡ Mercury is found also in Hungary and China; it occurs most commonly in argillaceous schistus, lime-stones, and sand stones. It is found in Sweden amalgamated with silver, and, frequently, combined with sulphur. Running mercury is found in globules, in earths and stones, in America, and collected from the clefts of the rocks there. Cinnabar, or sulphuret of mercury, is generally found also in those countries which produce the fluid metal. To extract the metal from the cinnabar, this ore is mixed with quick-lime and then submitted to heat. The lime combines with the sulphur, and the mercury which sublimes from the mixed mass is collected in receivers. An account of the whole process may be seen in the Memoirs of the French Academy for 1776. See also Note, page 194.

According to Proust, mercury is found mixed with all marine salts; and the muriatic acid of commerce contains mercury in the state of corrosive sublimate, arising from the mercury naturally mixed with sea-salt. Nicholson's Journal. vol iii. 4to. 375.

§ We see mercury always in a *fluid* state, because it is so very fusible that a small portion of caloric is able to keep it in a state of fludity. All metals require different portions of heat to fuse them. Lead melts with so little heat, that when first melted the hand may be plunged in it without occasioning pain; whereas gold requires the heat of 32 of Wedgwood to melt it, and platina a much stronger heat. Mercury, when submitted to a sufficient degree of cold, is similar in appearance to other metals, and may be beaten out into plates. It has been determined that 39 degrees below zero of Fahrenheit's thermometer is the point at which the congelation of mercury takes place. At the poles quicksilver would be uniformly solid.

ed*; extremely divisible; and is the heaviest of all the metals except platina and gold†. It readily combines with several of the other metals, and forms with them what are called amalgams.

What effect has oxygen *upon mercury?*

Mercury does not readily combine with oxygen‡, even though a very extended surface be exposed to the action of atmospheric air; but it has been oxidized by an uninterrupted application of heat for some months. Acids are usually employed to oxidize it§.

What salts *are there of mercury?*

There is a great variety of mercurial salts; but the acetate, the sulphate, the nitrate, and the muriate of mercury are best known. The latter is found native in the Palatinate‖.

What are the uses *of mercury?*

Mercury is used in large quantities for silvering mirrors, for

In the winter of 1799, Mr. Pepys froze 56 pounds of mercury into a solid and malleable mass. A *minute* account of the process by which he effected it may be seen in the Philosophical Magazine.

* Mercury is a substance so volatile that it may be distilled like water. It is sometimes purified in this way from a mixture of other metals. It is also so elastic when in a state of vapour, that it is capable of bursting the strongest vessels. There is no better way of ascertaining the purity of mercury than by distillation.

† According to Mr. Biddle, the specific gravity of mercury at 47 degrees above zero is 13.545; but when frozen into a solid at 40 *below* zero, 15.612.

‡ Mercury will not *burn* eitheir in atmospheric air, in oxygen gas, or in oxygenized muriatic gas. The same may be said of gold and silver; which has induced Dr. Thomson to exclude these three metals from the class of combustibles. See his Essay on Combustion, in Nicholson's Journal.

§ Mercury may be readily oxidized by dissolving it in nitric acid, and then precipitating it from its solution by the addition of a pure alkali, or by exposing the solution to a proper degree of heat to expel the remaining acid. It is capable of four degrees of oxidizement.

The beautiful scarlet pigment called *vermilion* is prepared from mercury. It is the red sulphuretted oxide of mercury. Europe has hitherto been furnished with it by the Dutch manufacturers, of greater beauty than any which has been procured from other markets; though it is said that even this article is inferior in splendour to that which is manufactured in China.

‖ Several salts are formed with this metal by art for medicinal purposes; viz. *Keyser's pill*, which is an acetate of mercury; *Turbith mineral*, which is said to be a sub-sulphate of mercury; *Red precipitate*, or oxide by means of the nitric acid; *Calomel*, or mild muriate of mercury; and *Corrosive sublimate*, which is an oxygenized muriate. Besides these there is a preparation called *Precipitate perse*, which is a true oxide of the metal; and *Ethiops mineral*, and *Cinnabar*, which are both combinations of mercury with sulphur.

One of the most valuable of the above salts is *calomel*, which is made by triturating fluid mercury with corrosive sublimate, and then submitting the mixture to sublimation. As this medicine is much used in private families, and as dreadful consequences might ensue if it were improperly prepared,

water gilding*, for making barometers and thermometers, and in the manufacture of vermilion. It has also various and important uses in medicine†.

How is copper *procured?*

Copper is found in several parts of England and Wales, particularly in Cornwall, and in the isles of Man and Anglesea. It is an abundant metal, and has been raised in various other parts of the world‡.

Of what nature *is copper?*

it ought to be generally known, that if it be not perfectly insipid to the taste, and indissoluble by long boiling in water, it contains a portion of oxygenized muriate of mercury, or corrosive sublimate, and is consequently poisonous.

* See Additional Notes, No. xxix.

† A fulminating powder has also been made with this metal, which might be advantageously employed for blasting rocks instead of gunpowder. This is said to have been discovered by Mr. Howard, and is usually called "Howard's fulminating powder:" but a friend of mine has a pamphlet, published many years ago, which states that fulminating mercury was prepared by the author; who, perhaps fortunately for him, was not aware of its dangerous nature.

In South America mercury is used to separate gold and silver from the extraneous matter found with those metals. By triturating the mass with mercury, the gold and silver become amalgamated with it; and afterwards, this amalgam is submitted to heat, when the mercury sublimes, and the perfect metals are left in a state of purity.

Several of the uses of mercury were known to the ancients. Theophrastus, an ancient Greek philosopher, who wrote about 300 years before Christ, was acquainted with it, and knew how to work it so as to form vermilion.

‡ Copper mines have been worked in China, Japan, Sumatra, and in the north of Africa. Native copper is found in Siberia crystallized in cubes. The copper pyrites found in Cornwall and upon several parts of the English coast are *sulphuret* of copper. Anglesea yields more than twenty thousand tons of copper annually. The vein of metal is more than 70 feet thick. Dr. Black, vol. ii. 647. See Additional Notes, No. xxxii.

Native oxides of copper are found in Cornwall and in South America. Carbonate of copper occurs as a natural production, and is called *malachite*.

Copper mines have not been worked in England above 150 years. Before that period, whenever the workmen met with copper ore in the tin mines of Cornwall, they threw it aside as useless no one at that time knowing how to reduce it to a metallic state. To chymical science, therefore, we are entirely indebted for such an ample supply of this valuable metal. See Additional Notes, No. xxxiii.

Copper was the only money used by the Romans till the 485 year of their city, when silver began to be coined. In Sweden, houses are covered with this metal.

When miners wish to know whether an ore contains copper, they drop a little nitric acid upon it: after a little time they dip a feather into the acid and wipe it over the blade of a knife; and if there be the smallest quantity of copper in it, the copper will be precipitated on the knife. A better mode of ascertaining the fact, perhaps, could not be devised.

Copper is of a red colour, very sonorous* and elastic†, and the most ductile of all the metals, except gold.

What is the effect of oxygen *upon copper?*

Copper will in some measure become oxidized by long exposure to atmospheric air, in which case its surface will be covered with the green oxide called verdigris‡. It is susceptible of two degrees of oxidizement§.

What salts *of copper are there?*

There are many salts of copper; but those most used are, sulphate of copper‖, acetate of copper¶; nitrate, muriate, and

* It is on account of this property that copper is chosen for making trumpets and other musical instruments.

† Copper, on account of its elasticity, is used by rope-dancers, &c. A wire 1-10th of an inch diameter will support near 300 pounds.

Copper will not burn so easily as iron; which is evident from its not striking fire by collision like iron. On this account this metal has been substituted for iron in the machinery which is employed in gunpowder mills.

Copper does not enter into combustion till it has acquired a heat more than sufficient to melt it. But if kept in a stream of oxygen gas, it will burn with a vivid blue flame.

Oxide of copper is soluble in ammonia, and precipitable from its solution by sulphuretted hydrogen.

‡ In domestic œconomy the necessity of keeping copper vessels always clean is generally acknowledged; but it may not perhaps be so generally known, that fat and oily substances, and vegetable acids, do not attack copper while *hot*; and, therefore, that if no liquid be ever suffered to grow *cold* in copper vessels, these utensils may be used for every culinary purpose with perfect safety.

§ Copper beginning to be oxidized is brown and reddish; a little more oxygen renders it blue; whereas a perfect oxide of this metal is of a bright green.

‖ Roman vitriol, much used by dyers and in many of the arts, is sulphate of copper. Fowling-pieces and tea urns are browned by washing them with a solution of this salt. *Verdigris* is an acetate of copper. *Blue verditer*, much used in staining paper for hanging rooms, is a nitrate of copper combined with carbonate of lime. The beautiful *grass green* colour of the shops, called *mineral* green, is a muriate of copper. The colour known by the name of *Scheele's* green is an arseniate of copper. The colour called *Brunswick* green is a triple salt, formed with potash, copper, and the tartaric acid.

Sulphate of copper is frequently found in the streams of water in copper mines: these waters were suffered to run to waste, till an attention to chymical affinities taught the proprietors of these mines how to turn them to a good account. The quantity of salt which they contain is not sufficient to reimburse the expense of boiling it down to blue vitriol; but by throwing waste iron into these waters the salt becomes decomposed, and the copper is precipitated in a metallic form. This is owing to the sulphuric acid having a greater affinity for iron than it has for copper. In the isle of Anglesea this principle is turned to an advantageous account.

¶ An account of the process of making verdigris at Montpellier may be seen in Annales de Chimie, tom. xxv. 305. Mr. Hume, of Long-Acre, has produced a very useful pigment by the combination of this metal with the prussic acid, Phil. Mag. vol. xx. 142.

arseniate of copper, and the tartrate of potash and copper. Besides these, which are generally formed by art, the carbonate, the arseniate, the phosphate, the muriate, and the sulphate of copper are found in a native * state.

What are the uses *of copper?*

The uses of this metal are too various to be enumerated. Besides its employment to make vessels of capacity, and to sheathe the bottoms of ships, it is alloyed with zinc to make brass†, and when combined with sulphuric acid forms Roman vitriol‡. Its oxides are employed in enamel painting, and in the manufacture of several colours.

What is the origin of iron?

Iron is plentifully and universally diffused throughout nature. It may be detected in plants§ and in animal fluids. It is found in great masses, and in various states, in the bowels of the earth in most parts of the world||.

* The ore of copper, called *malachite*, is a native carbonate of copper. The green sand brought from Peru is a native muriate of copper. A phosphate of copper, containing 30 per cent. of phosphoric acid, has been found near Cologne. The arseniate of copper occurs plentifully in the Huel Garland mine in Cornwall; and sulphate of copper has been found in some mineral waters.

† Brass is never made with pure zinc, but generally with calamine, which is a native oxide, or, rather, carbonate of zinc. Bishop Watson is of opinion that the *orichalcum* of the ancients was the same as our brass. Pliny says that the best mirrors were anciently made with a mixture of copper and tin; but that in his time those of silver were so common, that they were used even by the maid servants. These metallic mirrors were very much in request among the ancient nations. The Egyptian women, whenever they went to their temples, carried one of these mirrors in the left hand. A process for separating zinc from brass will be found in Ann. de Chim. tom. xxxviii.

‡ In order to make Roman vitriol, the copper is first oxidized by the following process: Plates of copper are heated red hot in an oven, by which means they become quickly covered with a crust of oxide, which separates as the plates cool; for the metal contracts much on cooling, though the oxide contracts but little, if at all.

Oxide of copper is used by the coloured-glass-makers. It forms a beautiful *green* glass.

Mr. Sage has shown that copper combined with phosphorus acquires the hardness of steel, is susceptible of the finest polish, and does not become altered in the air. Phil. Mag. vol. xx. p. 159.

Copper is used also in making princes-metal, gun-metal, bell-metal, tombac, and some other mixed metals.

§ Iron has been found in metallic grains in strawberries. It is said that oak wood when dried contains one-twelfth of its weight of this metal.

|| There is a great variety of iron ores (chiefly composed of the oxides of iron and clay), which have different names given them by the workmen, and are of very different qualities; for which consult Bergman, Kirwan, and others.

Metallic iron has been found *native* in Siberia and in Peru; some of the

What is the nature *of iron?*

Iron is soft and ductile*, has a styptic taste, and emits a peculiar smell when rubbed. It is attracted by the magnet, and has the property of becoming itself magnetic†. It also takes fire by collision with flint.

French chymists are of opinion that iron owes its origin to decayed plants and animals. See Add. Notes, No. xxxviii.

Iron is found in greater abundance than any other metal. In the northern parts of the world whole mountains are formed of iron ore, and many of these ores are magnetic. Of the English ores, the common Lancashire hematite produces the best iron. See Add. Notes, No. xxxv.

In the great iron works, the ore, broken into small pieces and mixed with substances to promote its fusion, is thrown into the furnace; and baskets of charcoal or coaks in due proportion are thrown in along with it. A part of the bottom of the furnace is filled with fuel only. This being kindled, the blast of the great bellows is directed on it, and soon raises the whole to a most intense heat: this melts the ore immediately above it, and the reduced metal drops down through the fuel and collects at the bottom. The rest sinks down, to fill up the void left by the consumed fuel and metal: this, in its turn, comes next in the way of the bellows, and is also reduced. More ore and fuel are supplied above, and the operation goes on till the melted metal at the bottom, increasing in quantity, rises almost to the aperture of the blast: it is let out by piercing a hole in the side of the furnace, and then forms what are called *pigs* of cast iron. Dr. Black, vol. ii. 400.

The rationale of making iron from the ore is well explained by Dr. Thomson, in his System of Chymistry, vol. i. 156. See also an excellent paper by Mr. Collier, in the Manchester Memoirs, vol. v.

* An iron wire, only one-tenth of an inch in diameter, will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry near 900 pounds. Black.

Iron is of a livid blueish colour, very hard, and the most elastic of all the metals. Its specific gravity varies from 7.6 to 7.8.

Iron becomes soft by heat, and has the capability of being *welded* to another piece of iron, both being sufficiently heated, so as to form one entire mass. No other metal possesses this singular property, except platina. Notwithstanding this, pure iron is nearly infusible. In order to effect the fusion of this metal, it is necessary to surround it with the fuel, and to urge the fire to the utmost possible pitch. Crude or pig iron is fused readily: hence, it may be cast into any form, and is employed in the fabrication of a vast variety of machinery and utensils.

† The advantages which we derive from the magnetic property of iron are incalculable. To this astonishing property we are indebted for an instrument—the mariner's compass—by which man is enabled to traverse the ocean, to open a friendly or commercial intercourse with every quarter of the world, and to steer his course towards any particular country with the utmost accuracy and certainty.

> Tall navies *hence* their doubtful way explore,
> And ev'ry product waft from ev'ry shore;
> Hence meagre want expell'd, and sanguine strife,
> For the mild charms of cultivated life.
>
> BLACKLOCK.

Prussiate of potash is the usual test for iron. When added to a liquid

Is iron always used in the state in which it is procured from the ore?

No: iron is employed in three states, viz. that of *cast* iron*, *wrought* iron†, and *steel;* each of which is of a different quality, and used for different purposes.

What constitutes the difference in these three kinds of iron?

Cast iron is the metal in its first state, rendered fusible by the combination of carbon and oxygen‡. *Wrought* iron differs from the former, in being deprived of this carbon and oxygen by continued heat and repeated hammering, which operations render it malleable§. *Steel* is made of wrought iron by various processes, whereby the metal resumes a small portion of carbon, and acquires the capacity of receiving different degrees of hardness‖.

which contains iron, it will cause a blue precipitate, if the iron has its full complement of oxygen; but if the iron is partially oxidized the precipitate will be gray. Succinate of ammonia will precipitate oxide of iron from its solutions.

* To convert *cast* into *wrought* iron, the former is kept in a state of fusion for a considerable time, and by repeated stirring in the furnace, the oxygen and carbon which it contains form an union, and rise from the mass in the state of carbonic acid gas. As the carbon and oxygen thus go off, the iron becomes more infusible; it gets thick or stiff in the furnace; and the workmen know by this appearance that this is the time to remove it from the fire, and to submit it to the action of the hammer; by which the remaining impurities are beaten out, and the metal is rendered malleable, ductile, and totally infusible.

† In purchasing wrought iron, the workmen distinguish two kinds which are of very inferior value. They are called *hot-short* and *cold-short* iron. The former is a fusible metal, which possesses ductility when *cold*, but is very brittle when *heated*. The cause of this variety is not known. The latter kind is very malleable and ductile while *hot*, but utensils made with it are as brittle as cast iron when *cold*. Such iron contains a portion of *siderite*, or *phosphuret of iron*.

‡ Cast iron which breaks of a *white* colour should be refused, as it contains a portion of phosphate of iron.

§ Though iron is deprived of part of its carbon and rendered malleable by hammering, *too much* hammering will deprive it of its malleability. Dr. Black is of opinion that this was owing to its losing part of its latent caloric by the operation, and that all metals are malleable in proportion to the matter of heat which they contain in a latent state. Lectures, vol. i. p. 139.

‖ Steel contains carbon like cast iron, but is divested of oxygen, which is always combined with the latter.

If a slender rod of wrought iron be plunged into cast iron in fusion, it will absorb part of the carbon and become steel. What is called *case-hardening* is a conversion of the *surface* of iron into steel.

Mr. Morveau exposed a diamond to intense heat, shut up in a small cavity in a piece of tough iron. When he opened the cavity he found the diamond entirely gone, and the iron around it converted into steel. Annales de Chimie, tom. xxxi. 328. This is one proof that the diamond is carbon, and shows that it is *pure* carbon, which combines with iron to form steel, and not · which is an oxide of carbon.

What is the effect of oxygen *upon iron?*

Iron has such an affinity for oxygen, that it will become oxidized merely by exposure to the air. The oxides of iron are found in great plenty ready formed in the bowels of the earth. This metal is susceptible of two degrees of oxidizement*.

What salts *of iron are there?*

Some of the salts of iron, such as the sulphates, the nitrates, the muriates, and the acetates, are of great importance in our manufactures†; besides which, many other salts of this metal have been formed. Arseniate, sulphate, phosphate, chromate, and tungstate of iron, have all been found native‡.

Steel may, by repeatedly heating and hammering it, be converted into wrought iron.

A steel instrument may be known from one of iron thus: If a drop of nitric acid be let fall upon it, it will occasion a black spot if it be steel, but will not have this effect if it be wrought iron.. The blackness is owing to the carbon of the steel acquiring oxygen from the acid, which forms it into charcoal.

Cast-steel is manufactured in some parts of this kingdom with great secrecy; but it is now known that it may be made merely by fusing it in an intense heat with carbonate of lime. Cast steel contains more carbon, and is more fusible than common steel.

* There is a *black* oxide of iron, and a *red* oxide; the latter contains nearly twice as much oxygen in a given portion as the former. The scales which are detached from forged iron by a high degree of heat, and which Dr. Priestley employed in several of his last experiments in America under the name of *finery cinder*, are in the state of the former. The iron contained in martial pyrites is in the state of an oxide combined with sulphur. The super-sulphuret of iron in this mineral is converted into *sulphate* of iron at the great copperas works, by exposing the pyrites to the air and rain for several months, in large beds prepared for the purpose. The sulphur decomposes the water which falls upon the beds, and is itself converted thereby into sulphuric acid, which combining with the iron forms the salt in question. This is afterwards extracted from the mass by lixiviation and crystallization. This process is carried on upon a large scale at Deptford, near London, where the united acidifying powers of air and water are exemplified in the great, well worth the notice of those who delight in prying into the secrets of nature.

Besides the above, Vauquelin has lately discovered a *blue* oxide of iron. See Additional Notes, No. xl.

The common hematite contains the *black* oxide; iron rust is the *red* oxide, combined with carbonic acid.

† *Green vitriol*, which is of so much use in dyeing, in making hats, and in other manufactures, is a sulphate of iron, formed, as has already been described, by the decomposition of martial pyrites. The nitrates, muriates, and acetates of iron, are formed by art for the use of calico printers, who consume great quantities of these salts in a state of solution.

‡ The native arseniate of iron is found in Cornwall; native sulphate of iron occurs frequently with pyrites; *phosphate of iron* ready formed occurs frequently in bogs—it is called native Prussian blue; chromate of iron has been found in France and in Siberia; and tungstate of iron exists native in a

What are the uses of iron?

The uses of iron are innumerable; every thing we possess is manufactured by its means; it is the most useful substance in the world*. When converted into steel it is employed in various ways, especially in making edge-tools, from the ponderous pit-saw to the finest lancet†. Its oxides are used in painting, enamelling, dyeing, and in medicine.

mineral found in Britain and elsewhere, called wolfram. The sparry iron ore is a carbonate of iron.

Carbonate of iron is commonly found in solution in chalybeate waters: such waters may be known by the dark orange-coloured film which generally appears upon their surface. The oxide of iron is rendered soluble by its union with carbonic acid. This may be shown by adding a few grains of quick-lime to a small quantity of such water; the lime will combine with the carbonic acid, the yellow colour will disappear, and the oxide of iron will be precipitated.

Besides the above, *carburet* of iron (usually called *black lead*) is found in several parts of the world. A combination of iron and silex also occurs native, and forms what is called *emery*; a substance very useful in the arts. It is employed by lapidaries, and by glass-cutters in cutting glass and stoppering bottles for chymical and other purposes.

Iron was in use in the time of Moses. Deut. iv. 20. viii. 9. and xviii. 5. The Greeks understood the method of tempering it. Homer describes the fire-brand dropt into the eye of Polyphemus as hissing like hot iron immersed in water.

* The property of *welding*, which, except platina, no other metal possesses, renders iron the most suitable of all others for every common purpose. It becomes soft by heat, and thus may be moulded by the hammer into any form, and united in as many parts as the workman pleases, without rivets or solder.

Fourcroy says, iron is the only metal which is not noxious, and whose effects are not to be feared. Indeed, its effects on the animal economy are beneficial. For a detailed account of its various and important uses in medicine, consult Fourcroy's Elements, Thomson's edition, vol. ii. 466, and following pages.

The ancients had an idea that iron was poisonous, and that wounds made with iron instruments healed with difficulty. Hence, after the expulsion of the Tarquins, Porsenna stipulated with the Romans that they should not use iron except in agriculture.

† The excellence of the edge-tools depends upon the temper given to them by heat. This requires great skill and peculiar management. A valuable report on the art of making fine cutlery may be seen in Nicholson's Journal, 4to. vol. iv. 127.

Sulphate of iron is not only used by the hatters and dyers, but also in making ink, in the manufacture of Prussian blue, in preparing leather, and in forming colcothar for painters. Colcothar is nothing more than sulphate of iron calcined to redness. It not only makes an useful pigment, but is employed in polishing different kinds of metals. It is from the iron which it contains that a piece of an old hat is useful for the same purpose. The oxide of iron imparts its colour to a great variety of natural substances. It is the cause of the redness of common bricks; it gives colour to the cornelian, the oriental ruby, the garnet, and other precious stones. With different proportions of oxygen it imparts other and different colours. Thus it gives

Where is tin *procured**?

Tin is found in Germany, in Saxony, and in the East Indies; but in England it is chiefly procured from Cornwall† and Devonshire.

What is the nature *of tin?*

Tin is a white metal, of little elasticity, and but little taste. It is the lightest‡ of all the metals, and so exceedingly soft and ductile that it may be beaten out into leaves thinner than paper.

What is the effect of oxygen *upon tin?*

Tin is susceptible of two degrees of oxidizement, forming the yellow§ and the white oxide; one of which contains 20, the other 28 per cent. of oxygen.

What salts *of tin are there?*

The muriate, the nitrate, the nitro-muriate, and the sulphate of tin are most known; but many other salts may be formed with this metal. None of the salts of tin have been found native.

the blue to the lapis lazuli, the yellow to the topaz, &c. See Add. Notes, No. xl.

* Tin must have been known very early, as it is mentioned in the books of Moses. The edge tools of the ancients, and their coins, were made with mixtures of copper and this metal.

Tin is found only in the primitive mountains. Tin ores occur most frequently in granite, but never in limestone. About 3000 tons weight of tin are furnished annually in Cornwall. Sulphuret of tin and the brown oxide of tin are often found in the same county. See Add. Notes, No. xxx.

† According to Aristotle, the tin mines of Cornwall were known and worked in his time. Diodorus Siculus, who wrote about forty years before Christ, gives an account of the method of working these mines: he says that their produce was conveyed to Gaul, and from thence to different parts of Italy. The miners of Cornwall were so celebrated for their knowledge of working metals, that about the middle of the seventeenth century the renowned Becher, a physician of Spire, and tutor of Stahl, came over to this country on purpose to visit them; and it is reported of him that, when he had seen them, he exclaimed, that "he who was a *teacher* at home, was a *learner* when he came there."

‡ The specific gravity of tin is 7.291, or about 516 pounds to the cubic foot: though the lightest of all metals except tellurium, it is much heavier than earths or stones.

Tin is much more combustible than many of the metals. It will burn in oxygen gas before it acquires a heat sufficient to fuse it.

Tin is soluble in all the mineral acids. It may be precipitated from its solution by potash; but an excess of potash will re-dissolve the metal. Nitro-muriate of gold is a test for the presence of tin in solution, forming a fine purple precipitate.

§ The *yellow* oxide of tin may be procured by dissolving granulated tin in very dilute nitric acid, and precipitating it from the solution by an alkali. The *white* oxide may be prepared by pouring very strong nitric acid on granulated tin. The metal in this case will not dissolve, but will be found at the bottom of the vessel in a pulverulent form. The liquor may be poured from it, and the oxide will only require to be washed for use.

What are the uses *of tin?*

Tin is consumed in large quantities by the dyers*; it is used also for covering sheet iron to prevent its rusting†, and in forming plumbers' solder, and pewter. Its oxides are used in polishing glass, in glazing some kinds of earthen ware; and for various other purposes‡.

What is the use of tin to the dyers?

Tin is employed by the dyers to give a brightness to cochineal, archil, and other articles used in forming reds and scarlets, and to precipitate the colouring matter of other dyes; for which purposes it is previously dissolved in a peculiar kind of aqua-fortis, called *dyer's spirit*§.

What is the nature *of lead?*

Lead is a heavy metal, of a pale lived white colour; slightly sonorous, and has scarcely any taste; but emits a peculiar smell

The oxide of tin found in commerce is called putty. It is employed in polishing fine steel goods, and the best kinds of ornamental glass.

The *white* oxide of tin is used to form the opake kind of glass, called enamel. This is made by calcining 100 parts of lead and 30 parts of tin in a furnace, and then fluxing these oxides with 100 parts of sand, and 20 of potash. But I am of opinion that soda would answer the purpose better than potash. To this enamel every kind of colour may be given by metallic oxides.

Tin by means of the muriatic acid decomposes water, and becomes oxidized thereby when the muriatic acid dissolves it, and forms muriate of tin. A solution of this metallic salt has a great affinity for oxygen. It de-oxygenizes a solution of indigo in an instant, and changes it from blue to green.

* Tin is used in forming boilers for the use of dyers, worms for rectifiers' stills, and for many other utensils employed in the arts.

† The consumption of tin for covering thin rolled iron, and forming what are improperly called sheets of tin, is very considerable: besides this, tin is used for coating the inside of iron and copper utensils, brass and iron pins, &c. For the method of doing this, consult Additional Notes, No xxx. or Gren's Principles of Chymistry.

The use of tin was known to the Grecians. Homer mentions it in the Iliad. Pliny says, the Romans learnt the method of tinning their culinary vessels from the Gauls. They used tin also to alloy copper for the purpose of making those elastic plates which they employed in shooting darts from their warlike machines.

Tin is employed to form bell-metal, the metal of which cannons are cast, and bronze. The addition of tin renders copper more fluid, and disposes it to assume all the impressions of the mould.

‡ A combination of the white oxide of tin with sulphur by means of mercury, forms *aurum musivum* (mosaic gold), an article used by artists to give a beautiful colour to bronze. I suspect that the change produced in tin by this process gave rise to the idea of the transmutation of metals. If the alchemists were acquainted with this substance, no wonder that they should indulge the hope of being able to form gold. An experimentalist without theory is the dupe of every illusion.

§ Several of the colouring substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable by the

on friction. It has little elasticity, and yields readily to the hammer, being the softest of all metals. A small portion of silver* is generally combined with it, and sometimes mercury.

Where *is lead procured?*

Lead ore is found in great abundance in Scotland, in Derbyshire, and many other parts of the world†.

use of this metallic solution; though a considerable degree of nicety and judgment is requisite for its preparation; so much so, that there are many large dyers who can seldom prepare it so well as those who make it an article of trade, and are fully acquainted with its chymical properties and effects. The difficulty is in a great measure owing to the nature of the spirit they use; as those makers of aqua-fortis who know nothing of chymical affinities, or of the nature and operation of this invaluable mordant, often furnish them with an article which is unfit for their use. Few arts have received such improvements from chymistry as the art of dyeing; for even cochineal gave but a dull kind of *crimson* till a chymist of the name of Kuster, about the middle of the seventeenth century, discovered the use of solution of tin, and the means of preparing with it and cochineal a durable and beautiful *scarlet*.

* Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased the lead rises to the surface combined with all heterogeneous matters. The art of refining the precious metals is built upon this property of lead.

Lead, when dissolved in acids, has the property of imparting a saccharine taste to substances with which it may be mixed. The ancients knew that this metal rendered harsh wine milder, but did not suppose that it was poisonous. According to Pliny, the Greeks and Romans proved the quality of their wines by dipping a plate of lead in them. Beckmann's History of Inventions, vol. i. 398, 400. I have a treatise on the management of wines, printed so lately as 1783, which directs the use of lead in order to preserve them from acidity. How much is the present age indebted to chymical science, which instructs us respecting the properties of different substances! Probably some of our wine-merchants, in consequence of this direction, may have contaminated their wines with lead, without suspecting that they were distributing a slow poison to their customers. For the effects of lead on the animal system, consult a late work by Dr. Lambe, on the Nature of Spring Water. See Additional Notes, No. xxxi.

† Lead-ore is generally found in veins, both in siliceous and calcareous rocks. Galena, or sulphuret of lead, is very common both in masses and crystallized. Lead is also found combined with silver, antimony, sulphur and bismuth. Oxides of lead combined with various earths also occur in mining countries. Lead ochre is a native oxide of lead.

Lead was in common use among the ancients. The Romans sheathed the bottoms of their ships with sheet lead, fastened on by nails made with bronze. During the first century, lead at Rome was twenty-four times as dear as it is now in Europe; whereas tin was only eight times its present price.

Lead, in the state of ceruse, was in great request among the Roman ladies as a cosmetic. Plautus introduces a waiting-woman refusing to give her mistress either ceruse or rouge, because forsooth, in the true spirit of a flattering Abigail, she thought her quite handsome enough without them. Watson.

What is the effect of oxygen *upon lead?*

Lead is susceptible of four different degrees of oxidizement, producing four oxides of different colours; viz. the gray, the white, the red*, and the brown oxide†.

What salts *of lead are there?*

The salts of lead are very numerous; but the muriate, sulphate, carbonate, and acetate of lead‡ are those most known. The carbonate, murio-carbonate, sulphate, phosphate, molybdate, arseniate, and chromate of lead are native productions; though they may be formed by art.

What are the uses *of lead?*

Lead is employed to cover buildings, to form water-pipes, to make a great variety of vessels for œconomical and chymical purposes§; also in refining gold and silver‖. Its oxides are used for

The lead-ores which are found in the primitive slate mountains contain much silver, generally 8 or 9 per cent.

* If a portion of lead be melted in an iron ladle, a scum will quickly appear upon its surface; if this be removed, another will immediately arise; and in this manner the whole of the lead may be converted into a gray pellicle which is the *gray* oxide of lead. If this gray oxide be exposed to a low red heat in a reverberatory furnace, it will acquire a further dose of oxygen, and be converted into yellow massicot; and if the heat be continued it will at length be changed to the *red* oxide of lead.

† If nitric acid of the specific gravity 1.260 be poured upon the *red* oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown, or brilliant flea-brown powder. This is the *brown* oxide of lead, containing 21 per cent. of oxygen.

Lead may be converted into an oxide by heating it in a situation where it can have free access of atmospheric air. All the oxides of lead may be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead which is combined with flint-glass may be revived by melting the glass with any carbonaceous substance.

Fourcroy says, that all the oxides of lead have the property of absorbing carbonic acid from the atmosphere; and that if an oxide of lead be required in a state of purity, it ought to be defended from the access of air.

‡ Nitrate of lead, according to Mr. Hume, should always be preferred as a test to the acetate, which is liable to give false results. Phil. Mag.

Lead forms an insoluble compound with sulphuric acid. Hence sulphuric acid is sometimes used to detect the presence of lead; but the best test is Harrowgate-water. To the suspected water add a little of this mineral water; and if lead be present it will give it a dark brown, or blackish tinge. For a method of detecting the presence of lead in wines see Additional Notes, No. xxxi.

§ Sheet lead is made by suffering the melted metal to run out of a box through a long horizontal slit in its bottom, while the box is drawn by appropriate ropes and pulleys along the table, leaving the melted lead behind it in the desired form to congeal.

There is a considerable consumption of lead in making shot. See Add. Notes, No. xxvi.

‖ Litharge of lead is often used in the analysis of the ores of what are

dyeing and calico-printing; in the manufactures of glass*, earthen ware, and porcelain†; and in the preparation of various pigments.

What is the nature of nickel?

Nickel is a fine white metal, ductile and malleable, but of difficult fusion‡. Its specific gravity is 9. It is attracted by the magnet§, and has itself the property of attracting iron ‖.

How is nickel procured?

Nickel is found in several parts of Germany in an ore very similar to that of copper. It is also often found with cobalt; but the nickel of commerce is always impure¶.

What is the effect of oxygen *upon nickel?*

If nickel be exposed to atmospheric air in an intense heat, it is

called the *perfect* metals. It has the property of combining with all the metallic oxides, and of preventing their evaporation during the cupellation; while it separates them from those metals which do not become oxidized by heat only.

* Lead is used in making glass, in order to give a proper degree of weight to the glass, and a susceptibility of its being cut without breaking.

† The oxides of lead and tin were employed by the ancient Romans in the manufacture of earthen ware, &c.

The oxides of lead dissolved in various menstrua are used as embrocations, and for several other preparations, by the practitioners of medicine.

‡ M. Richter has lately been occupied in a series of experiments upon nickel. He has found that this metal in its pure state is very malleable, nearly as brilliant as silver, and more attractable by the loadstone than iron. It is generally combined with copper; but he has found a method of freeing it from that metal. He says, that when pure it is not liable to be altered by the atmosphere; that it is perfectly ductile, and has great tenacity. Its specific gravity when forged is 8.666.

§ Many chymists have imagined that nickel and cobalt are magnetic only in consequence of a portion of iron which they contain; but in a paper in Nicholson's Journal, 8vo. vol. iii. 286. Mr. Chenevix has shown, that these metals are really magnetic; and that when they appear to be destitute of this property, arsenic is combined with them.

‖ As nickel always contains iron, the iron disguises its properties, and prevents its nature being exactly known. This metal dissolves readily in several of the acids, and communicates to them a green colour; but sulphuric acid acts very slowly upon it, even with the assistance of heat. Nitric acid dissolves it more readily.

¶ The most abundant ore of this metal is a sulphuret of nickel, called *kupfernickel*, which is generally a compound of nickel, arsenic, and sulphuret of iron.

It is a curious circumstance, that all the specimens that have been examined of the stones which have been to said fall from the atmosphere contain iron alloyed with nickel. These stones, which have at different periods been seen to fall on every quarter of the earth, are supposed by many to be cast from a volcano in the moon. So lately as 1803 a shower of them fell in Normandy, which covered an extent of three quarters of a league long, and half a league broad. Several dissertations on this curious subject may be seen in the latter volumes of the Philosophical Magazine.

slowly oxidized, and then acquires an increase in weight of 33 per cent. We are acquainted with only one oxide of this metal*.

What salts *of nickel are there?*

Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. An arseniate of nickel has been found native †.

What are the uses *of nickel?*

Nickel is employed by the Chinese in making their *white* copper, which is a beautiful metallic compound; but it has not been much used in Europe, although it may be had in considerable quantities‡.

What is the nature of zinc?

Zinc is a very combustible§ metal, possessing but a small degree of malleability|| and ductility, except under certain circum-

* Oxide of nickel is found in combination with some stones; the oxide may be dissolved in a solution of ammonia, and is not precipitated by sulphuretted hydrogen.

According to M. Richter, the oxides of *purified* nickel are of a much more lively green colour than the ordinary oxides; and their solution in ammonia is of a pale blue colour.

The oxide of nickel is said to afford the French manufacturers of porcelain a very delicate grass green; and, like other metallic colours, bears the intense heat of their ovens without injury.

† For a description of this native salt, consult vol. ii. of Kirwan's Mineralogy.

‡ I have not heard that any use has been made of this metal in England. The Chinese use it in conjunction with copper and zinc for making children's toys. They have some method, unknown to us of combining these metals.

According to Proust, nickel, in a certain proportion, gives a degree of *whiteness* to iron, diminishes its disposition to rust, and adds to its ductility.

The valuable qualities which M. Richter has discovered in this metal, show that it might be applied to many important uses, particularly for surgical instruments, compass-needles, and other such articles, as it is not liable to rust. Should an easy mode of working it ever be discovered, we may possibly find this to be better calculated for a variety of purposes than any other metal.

§ Zinc is so very combustible, that if beaten out into thin leaves it will take fire from the flame of a common taper. It is the most combustible metal we have. It has so strong an attraction for oxygen that it will decompose water without the assistance of heat. Excepting manganese, it has the strongest affinity for oxygen of all the metals.

|| Messrs. Hobson and Sylvester, of Sheffield, have discovered, that at a temperature between 210° and 300° of Fahrenheit, zinc is really a malleable metal; that it yields to the hammer, and may be wire-drawn if kept at this temperature during the operation. They say, moreover, that after having been thus annealed and wrought, it continues soft, flexible and extensible, and does not return to its partial brittleness, but may be bended and applied to many uses for which zinc has hitherto been thought unfit. If so, this is an important discovery; and in future there will be no impediment to its

stances*. When broken, it appears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle which reflects various colours, in consequence of its affinity for oxygen and carbonic acid.

How is zinc procured?

Zinc, generally called by our artists *spelter*, is not found native†, but is extracted in England and elsewhere from calamine and other ores, by distillation‡.

What is the effect of oxygen upon zinc?

Zinc is readily oxidized by heat. When it acquires a white heat the whole sublimes; hence its oxide acquired the name of *flowers* of zinc. It may also be oxidized by acids. We are acquainted with two oxides of this metal, viz. the yellow and the white oxide.

What salts of zinc are there?

being formed into vessels of capacity, and into utensils for various manufactories; sheathing for ships' bottoms, &c.

* The nature of zinc is such, that it seems to form the link between the brittle and the malleable metals. It is difficult to procure it in small particles, as the hammer flattens it instead of reducing it to powder. Macquer says, that if it be heated very hot, it becomes brittle, and may then be pulverized.

† Some mineralogists consider zinc to be the most abundant metal in nature, excepting iron. Calamine, or lapis calaminaris, is found both in masses and in a crystallized state, and is generally combined with a large portion of silex. Calamine is a *native oxide* of zinc, combined with carbonic acid. Zinc is found also in an ore called *blend*. In this state it is mineralized by sulphur. Workmen call it Black-Jack—a mineral employed till lately in Wales for mending the roads.

In China there is great abundance of zinc;—it is used in that country for current coin, and is employed for that purpose in the utmost purity. These coins have frequently Tartar characters on one side and Chinese characters on the other. They have generally a square hole in the centre, that they may be the more readily counted and carried on strings.

‡ Metallic zinc is procured from calamine by distillation *per descensum*. The calamine is pounded, and with powdered charcoal put into large pots, and these pots put into a furnace like a common oven. These pots have tubes fixed in their bottoms, which pass through the bottom of the furnace into a vessel of water. After the tops of the pots are covered, and rammed close with clay, a strong fire is made around them, so that the metallic zinc, being separated from the ore, and being of a volatile nature, is forced to rise to the upper entrance of the tubes, and thence passes downwards into the water.

In order to analyse the ores of zinc, it is necessary to operate upon them in retorts, and to collect the distilled metal in close receivers; for, if reduced in a common furnace, the greater part of the produce would be dissipated by sublimation. The same attention is necessary when operating upon arsenic.

Zinc may be known by dissolving it in a mineral acid, and then adding ammonia, which precipitates it of a white colour, and re-dissolves it instantly. Sulphuretted hydrogen added to a solution of this metal produces a white and lasting precipitate.

A great number * of salts have been formed with this metal; but the carbonate and the sulphate of zinc† are most known, both of which are found native.

What are the uses *of zinc?*

Zinc is not only the base of white vitriol, but is combined with copper or tin, in various proportions, to form factitious metals‡: it is also used in medicine; and may be advantageously substituted for white lead in house-painting§.

What is the nature of antimony?

Antimony|| is a brilliant brittle metal, of a dusky white colour, and destitute of ductility. Though seemingly hard, it may be cut with a knife without much difficulty¶.

* Zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the metals, except manganese will precipitate it from its solutions in a metallic form.

† *White vitriol*, or sulphate of zinc, is usually formed in Germany from an ore called *blende*, which is a sulphuret of zinc. By the agency of fire and the access of atmospheric air, the sulphur is converted into sulphuric acid, and by means of proper evaporation and cooling the salt is obtained in a crystallized mass. Sulphate of zinc occurs also in some mineral waters.

Acetate of zinc has been recommended by Mr. Henry to be applied in cases of inflammation. This salt is easily formed by dissolving flowers of zinc in acetic acid.

‡ Three parts of copper, and one of calamine or native carbonate of zinc, constitute *brass*; five or six of copper and one of zinc form *pinchbeck*. *Tombac* has still more copper, and is of a deeper red than pinchbeck. *Prince's-metal* is a similar compound, excepting that it contains more zinc than either of the former. A mixture of tin and copper with zinc forms *bronze*. Vessels of bronze, covered with silver, were dug out of Herculaneum. In order to make *brass*, the calamine is previously roasted; it is then mixed with charcoal and grain copper, and put into large crucibles, which are kept for a considerable time in a heat that will not melt the copper; after a time, the heat is raised so as to fuse it, and the compound metal is run into ingots.

§ See Annales de Chimie, No. ciii.

Zinc, in fine filings, is used to mix with gunpowder, to produce those brilliant stars and spangles which are seen in the best artificial fire-works.

Zinc is generally one of the metals employed to form Galvanic batteries.

An amalgam of zinc is used to rub upon the cushions of electrical machines. It is very conveniently amalgamated, by melting it in a bowl of a tobacco-pipe, and pouring it while hot into the mercury. I have amalgamatized bismuth and other metals, but never found one of them to answer for electrical purposes equal to zinc, or an amalgam made with a mixture of tin and zinc.

|| According to Bergman, the specific gravity of antimony is 6.86. If this metal be ground fine, and thrown into a dry glass jar filled with oxygenized muriatic acid, it will inflame immediately, and continue to burn with great rapidity and with a brilliant white flame. The combustion affords a beautiful spectacle. It also fulminates by percussion with oxygenized muriate of potash.

¶ Antimony may be known from bismuth thus:—Bismuth is very soluble in nitric acid, but antimony dissolves in it with difficulty.

How is antimony procured?

Antimony is procured from an ore which is chiefly found in Hungary and Norway*.

What are the effects of oxgen *upon this metal?*

Antimony is susceptible of two degrees of oxidizement; the one oxide containing 18½, the other 23 per cent. of oxygen†.

What salts *of antimony are there?*

Many different salts have been formed with the oxides of this metal; but those most known are the muriate of antimony‡, the phosphate of lime and antimony§, and the tartrate of potash and antimony‖. The first has been found native.

What are the uses *of antimony?*

Antimony is combined with other metals in making printer's types and specula for telescopes. Its oxides are employed in medicine¶, and in colouring glass. In times of remote antiquity

* There are several ores of antimony, but the gray is the only one which is found in sufficient quantity for the manufacturer; it is a sulphuret of antimony. This ore is purified by exposure to a strong heat in a reverberatory furnace. By this process, the pure sulphuret runs from the earthy matter: this is afterwards remelted, and cast into cakes for sale. This sulphuret may be divested of nearly all its sulphur by long roasting, leaving the metal in the state almost of a pure oxide.

Native antimony, alloyed with a small portion of silver and iron, has been found in Sweden.

† It was formerly supposed that antimony was capable of forming six different oxides; but Proust has shown that it is susceptible only of two degrees of oxidizement.

If oxide of antimony be precipitated by water from nitro-muriatic acid, the precipitate will be white; but if it be precipitated by a clear solution of galls, the precipitate takes a light yellow.

Some solutions of the oxides of this metal are very powerful and even poisonous when taken internally, except in very small quantities. See p. xviii.

‡ Muriate of antimony is the common *butter of antimony* of the shops. The white oxide of antimony, called the *powder of Algoroth*, is prepared from a solution of this salt. Muriate of antimony has been found native in Bohemia.

§ The well-known medicine called *James's powder* is a phosphate of lime and antimony. It is a triple salt in the form of a white powder. For a method of preparing it, consult Phil. Mag. vol. xi.

‖ *Emetic tartar* is a tartrate of potash and antimony, composed of about 56 parts tartrate of antimony, 36 tartrate of potash, and 8 of water.

¶ Perhaps we have no metal more valuable as a medicine than antimony, or that is applied in such various ways. For particulars, consult the New Edinburgh Dispensatory, by Dr. Duncan, jun.

Kermes' mineral, and what was called *golden sulphur* of antimony, are both from the sulphuret of this metal, by means of potash. The first took its name from its resemblanee in colour to the kermes insect used in dyeing. The sulphuret, and some other preparations of antimony, are given to horses and cattle more than any other medicines. They act as alteratives, and are generally to be depended upon for the certainty of their effects.

it was used by females as a black pigment for staining the eye-lashes.

What is the nature * *of* bismuth?

Bismuth is of a yellowish white colour, of a lamellated texture, and moderately hard, but malleable. It is so brittle that it breaks readily under the hammer, and may be reduced even to powder†.

How is bismuth procured?

Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England. Native bismuth and sulphuret of bismuth are also found upon the continent; but it is not an abundant metal.

What is the effect of oxygen *upon bismuth?*

Bismuth oxidizes gradually by fusion in atmospheric air. It is susceptible of two degrees of oxidizement‡.

What salts *are there of bismuth?*

Several salts of bismuth have been formed, but their properties have not been much examined by chymists. Those most known are the nitrate§ and the muriate of bismuth‖. The salts of this metal are not found native.

* If water be added to a solution of bismuth in nitric acid, the oxide will be precipitated of a pure *white* colour; but if a little tincture of galls be poured into a similar solution, a *brown* precipitate will be produced. This is the distinctive characteristic of this metal.

† Bismuth has the singular property of *expanding* as it cools. Hence, probably, its use in the metallic composition for printers' types; as from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. In manufactories this metal is known to the workmen by the name of *tin-glass*.

Bismuth is one of the metals that will inflame when thrown into oxygenized muriatic acid.

‡ *Pearl-white* is an oxide of this metal. Ladies use it for painting the skin, to which it imparts a beautiful white; but it has the inconvenience of becoming black by the contact of sulphuretted hydrogen gas, or the fumes of fetid substances. The gas which arises from the burning of mineral coal will have the same effect. It is related of a lady of fashion, who had incautiously seated herself too near the fire at a quadrille table, that her countenance changed on a sudden from a delicate white to a dark tawny, as though by magic. The surprise and confusion of the whole party had such an effect upon the disfigured fair-one, that she was actually dying with apprehension, when the physician dispelled their fears, by informing his patient that nothing more was necessary than for her to wash her face, to abstain from the use of mineral cosmetics, and to trust in future to those charms which nature had bestowed upon her.

Some of the French chymists recommend the use of the oxides of bismuth for dyeing, to fix some particular colours. Pomatum prepared with the oxide of bismuth turns the hair black.

§ Nitrate of bismuth does not dissolve in water like other metallic salts, [illegible] parts a white colour to the water; hence, this metal is readily distin[illegible] from most others.

[illegible] *butter* of bismuth of the old pharmacopœias was the muriate of this

What are the uses *of bismuth ?*

Bismuth is used with other metals to form printers' types, and to make pewter*. Most metals become more fusible by an union with bismuth: hence, this metal is employed to make solder. Bismuth is likewise given in medicine, though now very rarely.

What is the nature† *of arsenic ?*

Arsenic, in a natural state, has more the appearance of a salt than a metal, being generally found in combination with acids‡, sulphur, or oxygen§. When reduced to its pure metallic state, it is a brittle brilliant metal, of a blueish white colour, easily tarnishing, that is oxidizing, by exposure to the air‖. In all states it is poisonous ¶.

Where is arsenic found ?

Arsenic is found in Bohemia, Hungary, Saxony, and other

Magistery of bismuth, as it was formerly called, or pearl-white, is a pure oxide, prepared by precipitation from the solution of nitrate of bismuth; it is obtained by pouring nitrate of bismuth into plenty of water, in which the oxide will subside. This must be well washed for use.

* The common mixture for *pewter* is 112 pounds of tin, 15 pounds of lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony in that factitious metal. Bismuth is likewise generally mixed with tin for vessels of capacity, &c. as it gives to that metal a greater degree of brilliancy and hardness.

If 8 parts of bismuth, 5 of lead, and 3 of tin be melted together, the mixed metal will fuse at a heat no greater than 212°. Tea-spoons made with this alloy are sold in London, to surprise those who are unacquainted with its nature. They have the appearance of common tea-spoons, but melt as soon as they are put into hot tea. A composition of lead, zinc, and bismuth in equal parts, will melt with so small a portion of caloric, that it may be kept in fusion upon *paper* over a lamp.

† Arsenic may be known by the smell of garlic, and by the white fumes which it exhales when thrown on a piece of red hot coal.

‡ Nitrate of arsenic will precipitate the salts of copper of a beautiful green colour. This precipitate is exactly the same as the *native* arseniate of copper found in the mines of Cornwall.

§ The oxides of arsenic in solution are discovered by sulphuretted hydrogen, which produces a yellow-coloured precipitate. This precipitate is the same as that beautiful ore found native, called orpiment (sulphuret of arsenic.)

‖ If arsenic in its pure metallic state be kept covered with alcohol, it will preserve its metallic brilliancy.

If metallic arsenic be previously inflamed, it will burn in oxygen gas till the whole is consumed. It burns with great brilliancy, and forms a very beautiful experiment.

¶ Dr. Pearson has said, that white arsenic, in the quantity of one-sixteenth part of a grain, is as harmless as a glass of wine, and in that dose is a remedy for inveterate agues. See Dr. Pearson on Sulphate of Iron, &c. Phil. Mag. vol. xxi. 56.

Whenever arsenic has been taken internally, by design or [illegible] the best medicine is sulphuret of potash (liver of sulphur) dissol[illegible] A few scruples should be dissolved in half a pint or a pint of [illegible] ministered a little at a time as the patient can bear it.

places on the continent* It is united with, and contaminates, many of our metallic ores in England†.

What is the effect of oxygen *upon arsenic?*

Arsenic has a great affinity for oxygen, and is susceptible of two degrees of oxidizement‡.

What salts *of arsenic are there?*

The salts which have been formed with this metal are few; muriate of arsenic was made by the old chymists, and called *butter* of arsenic. None of the salts of this metal are found native§.

What are the uses *of arsenic?*

Arsenic, in a reguline state, is used to whiten copper, and enters into the composition of several factitious metals for specula, &c.‖ Its oxides are employed in many processes of the dyer¶, also as fluxes for glass, and in several of the arts. The sulphurets of arsenic form valuable pigments of different colours**.

What is the nature *of cobalt?*

Cobalt is a whitish gray brittle metal, nearly resembling fine

* The arsenic of commerce is prepared in Saxony by roasting the cobalt ores for the manufacture of zaffre. White arsenic is prepared by mixing the common oxide with potash, and submitting it to sublimation. By this process the arsenic is separated, and sublimed, leaving its sulphur behind united to the potash.

In analysing the ores of arsenic, or the ores of any of the metals whose oxides are volatile, the upper part of the crucible should always be filled with charcoal; so that whatever is volatilized may be caught by the charcoal, and immediately reduced.

† Arsenic is frequently found in martial pyrites, and in copper ores. See Gellert's Metallurgic Chymistry, and Henkel's Pyritologia.

Lead, when contaminated by arsenic, may be purified by melting it with a few iron filings. The iron combines with the arsenic, and these, being lighter than the lead, float on the surface, from which it may be readily skimmed off.

‡ Arsenic is capable of combining with so large a portion of oxygen as to become changed into a perfect acid. See page 137. There are four other metals which are completely acidifiable; viz. chromium, molybdenum, tungsten, and columbium: there is, however, some doubt respecting the acidifiable nature of tungsten.

§ Though there are no native salts in which arsenic forms the base, yet we are acquainted with several in which it is combined as an acid; such are, the arseniates of lime, copper, iron, cobalt, &c.

‖ The use of arsenic, in making factitious metals for the specula of reflecting telescopes, may be seen in a long paper on that subject, by the Rev. John Edwards of Ludlow, in the Nautical Almanac for 1787.

Arsenic is used in making small shot. The design of it is to render the lead more brittle, and better capable of granulating. See Additional Notes, No. xxvi.

¶ Arsenic, when used in dyeing, is generally combined with potash. Baumé has long made a trade of preparing this salt for the French dyers.

** Sulphuret of arsenic is much used in calico-printing, on account of its property of readily dissolving indigo.

hardened steel*. It is difficult of fusion and oxidizement, but obedient to the magnet.

How is cobalt procured?

Formerly all our cobalt came from Saxony†; but it is now found abundant in the Mendip hills in Somersetshire, and in a mine near Penzance, in Cornwall‡.

What is the effect of oxygen *on this metal?*

Cobalt may be oxidized by an intense heat. The oxygen con-

Orpiment and realgar are both sulphurets of arsenic. Realgar is a dark orange or scarlet, the other a beautiful lemon colour. They are both much used in dyeing and calico-printing. The former has lately been found native in Cornwall. The pigment called *king's* yellow is made from this mineral. Beautiful shades of different colours may be given to valuable furs by arsenical solutions.—"So that that substance which is most injurious to the animal œconomy, appears to be endowed with properties for embellishing the works of creation, and is made to minister in various ways to our gratification, by imparting colour to other bodies. How diversified are the means which the God of Nature hath adopted for the promotion of these designs!

Who not content
With every food of life to nourish man,
By kind illusions of the wondering sense,
Has made all nature beauty to his eye,
Or music to his ear.

AKENSIDE.

Arsenic is used in preparing the beautiful colour called *Scheele's green*. For the method of making this colour, consult Gren's Chemistry.

The Chinese and other Orientals form realgar into medical cups, and use as a carthartic, lemon juice which has stood some hours in them.

* According to Bergman, its specific gravity is about 7.700; though Tassaert makes it to be 8.538.

Solutions of cobalt give a *green* colour by evaporation and heat. This may be shown, by moistening a little paper with the solution, or writing with it on paper, and drying the paper by a gentle heat. The oxide of cobalt in ammonia forms a red solution.

† The cobalt ores of Hesse, which at present produce a net profit of 14,000*l.* a year, were formerly used in repairing the roads. Born's Travels.

‡ Zaffre is now made from the cobalt ores found in these hills. Had it not been for the rapid promulgation of chymical science in these kingdoms, this important metal might have lain in the bowels of the earth undiscovered for ages yet to come.

Full many a gem of purest ray serene
The dark unfathomed caves of ocean bear;
Full many a flower is born to blush unseen,
And waste its sweetness on the desert air.

GRAY.

Cobalt ores generally contain arsenic; they are so contaminated with it, that the workmen who work in these mines seldom live many years. I-

converts it into that beautiful blue colour which is seen on earthenware and porcelain*. There are three different oxides of cobalt†.

What salts are there of cobalt?

A great variety of salts have been formed with the oxides of this metal; but the muriate of cobalt is that which has, perhaps, been longest known‡. An arseniate and a sulphate of cobalt have been found native.

What is the use of cobalt?

Cobalt has hitherto been chiefly used for making the different kinds of smalts for painting and enamelling§. It is extremely

may be hoped that some mode will be devised for protecting the men from the dust, &c., of this mineral. In the cobalt mines of Saxony, the separation of the arsenic is performed only by criminals who had been condemned to death.

Cobalt ores may be analysed thus: Take 100 grains of the ore, dissolve them in nitrous acid, precipitate the iron by the addition of ammonia, and separate it from the solution by a filter. The nickel, which is always found in these ores, may afterwards be precipitated by the addition of a solution of potash, and separated in the same manner as the iron. The remaining solution may be evaporated to dryness, and the oxide reduced by the usual fluxes.

The white cobalt ore is a sulphuret of cobalt. Arseniate and sulphate of cobalt have also been found native.

Cobalt, for experiment, might easily be obtained in a metallic state, by fusing *strewing smalt* with 6 or 8 times its weight of soda. The soda forms an union with the sand and leaves the cobalt free.

* The oxide of cobalt forms the most permanent blue colour that we are acquainted with. La Grange says that the old painters used this oxide mixed with oil in their paintings; which is the reason why the sky and drapery in some old pictures are of so durable a blue.

† Zaffre, which we have long imported from Saxony, is an oxide of cobalt, mixed with three times its weight of ground silex. There are the black, the brown, and the yellow cobalt ores, all which are oxides of this metal.

‡ Muriate of cobalt has been long used in forming a green sympathetic ink. Whatever is written on paper with this ink remains invisible, while it is cold; but if the paper be gently warmed, the letters will appear of a beautiful green colour:—thus, by warming or cooling the paper, the writing may be made to appear and disappear at pleasure. It is, however, from some iron generally found in cobalt that the muriate forms a *green* ink; for, if it be perfectly pure, it is always of a most beautiful blue; so that by proper management one may be provided with both. By means of these two inks, a picture of winter may be drawn which shall be transformed to a beautiful summer landscape, by holding it near the fire; and which will appear gradually to lose its verdure, and resume its winter dress, on being removed to a cold situation. The *acetate* of cobalt is always of a *red* colour in solution, but as a sympathetic ink it is a fine *blue*.

§ *Strewing smalt*, used by sign-painters, is made by melting the oxide of cobalt with flint glass, and grinding the mass to a coarse powder. The same composition reduced to an impalpable powder forms the smalts for washing, sold under the name of powder blue; which is not only used by laundresses, but is made the basis of several pigments.

valuable to the manufacturers of porcelain, as it endures the intense heat of their furnaces without any deterioration, and produces a finer colour than can be procured from any other known substance*.

What is the nature of manganese?

Manganese is a brilliant, heavy metal†, of a dark gray colour, of considerable hardness, and difficult fusibility. It is very brittle, and when in powder is attracted by the magnet.

Where is manganese found?

The manganese which is used in this kingdom is gotten in the state of an oxide in the Mendip hills, in Somersetshire, and at Upton Pyne, three miles from Exeter‡. It is found also in abundance in America, and on various parts of the continent.

A solution of cobalt in muriatic acid forms Hellot's sympathetic ink. See Add. Notes, No. xxvii.

Cobalt was employed to colour glass in the fifteenth century, and yet but small quantities of it have been used till lately. Formerly the miners threw it aside as useless. They considered it so troublesome when they found it among other ores, that a prayer was used in the German church that God would preserve miners from *cobalt*, and from *spirits*. Beckmann's History of Inventions, vol. ii. 363. Other ancient uses of this metal, as a colour, may be seen in the same work.

* The greatest consumption of cobalt is by the potters and porcelain manufacturers, some of whom make their own colour from foreign zaffre. But in Staffordshire there are several people who make an entire trade of preparing this colour for the earthen-ware manufacturers, and who conduct the process with great secrecy. The usual price of the prepared colour is two guineas the pound.

† The specific gravity of manganese has been estimated at 6.850 by Bergman.

For a method of procuring this metal in a metallic state see Dr. Thomson, vol. i. 242.

The oxides of manganese are abundant, but the *pure* metal is not so easily procured. The oxide requires to be intensely heated with a large portion of charcoal, in order to its being reduced to a metallic state.

Where manganese is employed in making oxygenized muriatic acid for medicine, the purest, such as that of Upton-Pyne, should be used. That from Bristol and the Mendip hills generally contains lead. Thornton's Medical Extracts, vol. v. 403.

‡ Manganese is generally found either in the state of an oxide or a salt. But the discovery of English mines of it is a new acquisition to this country, owing to the spirit of research which chymistry has given birth to.

Dr. William Dyce, of Aberdeen, has lately communicated to the Society for the Promotion of Arts, &c. the discovery of a mine of manganese in his vicinity, of great extent, and of very fine quality. The gold medal of the Society was awarded to him for this discovery. The present produce of the mine is 20 tons per week.

Oxide of manganese is frequently found in stones and minerals. When the mineral is dissolved, it may be precipitated from its solution by ammonia.

Scheele discovered this metal in the ashes of burnt vegetables.

What is the effect of oxygen *upon manganese?*

This metal will become oxidized by mere exposure to the air*. It is susceptible of three different degrees of oxidizement, forming the white, the red, and the black oxide of manganese†.

What salts *are there of manganese?*

A variety of salts have been made with the oxides of this metal; but this class of salts has not yet been rendered useful‡. A carbonate of manganese is found native in Norway and Sweden.

What are the uses *of manganese?*

The oxides of manganese are used in bleaching§, in purifying glass||, and in glazing black earthen ware. The black oxide is

Proust has lately announced the discovery of a *native sulphuret* of manganese.

* Manganese has such an attraction for oxygen, and becomes so soon oxidized by exposure to the air, that in order to preserve specimens in a metallic state it is necessary to varnish them, or to keep them immersed in oil, or ardent spirits.

† The methods of giving the different degrees of oxidizement to this metal may be seen in Dr. Thomson's Chymistry.

If one part of the black oxide of manganese, and three parts of nitrate of potash be melted in a crucible till no more oxygen gas is disengaged, a greenish friable powder is obtained, called *mineral cameleon*, from its property of changing colour when dissolved in water. If a small quantity of this powder be put into a glass of water, the solution is first *blue*; oxide of iron then separates, and by its *yellow* colour renders the solution green; this subsiding, the blue re-appears; then, as the oxide of manganese absorbs oxygen from the atmosphere, it becomes reddish, brownish, and at last black. It then subsides, and leaves the fluid colourless. Parkinson.

The *rubelite* and the *amethyst* owe their colours to the *red* oxide of manganese.

‡ There is a peculiarity attending the salts of manganese, that when dissolved in water, the manganese cannot be precipitated from its solution in a metallic state by any of the other metals. This is owing to manganese having an attraction for oxygen superior to that of all other metals.

§ Manganese is used by the bleachers in making the oxygenized muriatic acid, which has the property of destroying all colours.

|| Its use in glass-making may be seen in Berthollet's Treatise on Dyeing. It was employed for this purpose more than two thousand years ago.

Dr. Dyce has suggested that manganese may advantageously be employed in separating the pure from the baser metals. An account of the process may be seen in the last volume of the Transactions of the Society of Arts, &c.

According to monsieur Gazeran, manganese forms a component part of steel, and ought to be added to iron for its formation; the best German steel being, according to him, composed of

Iron . .	97
Manganese .	2
Carbon . .	1
	100

also much used by chymists for procuring oxygen gas, which it gives out in great abundance, by the application of a red heat.

What is the nature of tungsten?

Tungsten is a heavy metal, procured from a mineral found in Sweden, and from an ore called *wolfram*, found in our county of Cornwall, Germany, &c. but its properties are not much known, neither is it brought into any use here*. The same may be said of molybdenum†, uranium‡, titanium, tellurium, chromium§, columbium||, and tantalium¶. It will therefore be proper to defer the consideration of these metals till their properties are further investigated.

Having gone through the greater part of this chapter on metals, endeavour to recapitulate the general *properties of this class of bodies?*

The metals are simple substances**, distinguishable from all other bodies by their lustre, by their great specific gravity, by their perfect opacity, and by their superior power of conducting electricity.

What are the obvious advantages which we derive from these bodies?

The metals are the great agents by which we are enabled to explore the bowels of the earth, and to examine the recesses of Nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and

* Tungsten has been used in France for making vegetable lakes. Its oxide is insoluble in either of the three mineral acids, which is not the case with the oxide of any other metal. Though tungsten has been recommended as a proper basis for colours, it shows in some instances a strange fugacious disposition. Mr. Hume left a piece of zinc for some time in some of the triple acidulous solution, generally called tungstic acid, and obtained a most brilliant blue solution: this was placed over the gentle heat of a lamp to evaporate, and soon lost all its colour. Phil. Mag. vol. xix. 29.

† Molybdenum has been employed, I believe, in some processes of dyeing in Germany. As it may be procured in great plenty, it will probably some time hence come into general use here.

‡ Uranium, combined with carbonic acid, is found in the common green mica.

§ A beautiful green colour may be obtained from this metal useful for painting in oil or *distemper*, or for applying to porcelain. The metal was called chromium, because of its property of imparting *colour* to a variety of other bodies.

|| Columbium was discovered in a mineral sent from Massachusetts, in North America. See Mr. Hatchett's paper on this metal in the Philosophical Transactions for 1802.

¶ Tantalium was found in an ore from Swedish Lapland. Its characteristic is, that it is insoluble in all the acids.

** The ancient chymists supposed the metals were *compound* bodies. They were probably led to this by observing the pulverulent nature of the metallic oxides. Their undecompounded nature was first suspected by Mayo.

are even subservient in the progress of the human mind towards perfection*.

You can doubtless offer some reasons why one metal possesses such opposite and specific differences from another?

This variety is not to be attributed to chance, but must certainly be the effect of consummate wisdom and contrivance. These metals differ so much from each other in their degrees of hardness, lustre, colour, elasticity, fusibility, weight, malleability, ductility, and tenacity, that nature seems to have had in view all the possible necessities of man, to suit every purpose his ingenuity can invent or his wants require.

By what means are these bodies rendered so important to us?

We not only receive this great variety from the hand of Nature, but these metals are rendered infinitely valuable by various other *properties* † they possess. By their combustibility‡, their solubility in fluids, their combinations with phosphorus, sulphur§, and carbon, and by their union with each other||, whereby com-

* The metals are seldom afforded by Nature otherwise than in a state of great impurity. It is to the use of the reasoning faculty that we owe the possession of any of them in a state fit for use. If we consider for a moment what would be the situation of the world if society were deprived of this class of bodies, we should then have some idea of the obligations we owe to the sciences of metallurgy and chymistry.

———— "Serene philosophy,
Effusive source of evidence and truth!
Without thee, what were unenlighten'd man?
A savage roaming through the woods and wilds,
Rough clad, devoid of every finer art
And elegance of life." THOMSON.

The best information respecting the analysis of metallic ores may be had from Klaproth's Essays, to which I refer the reader.

† Much information on the nature of the metals may be collected from Mr. Hatchett's valuable paper on gold, in the Philosophical Transactions for 1803.

‡ Some of the metals are so combustible that they will burn before they acquire a heat sufficient to fuse them. This is the case with iron and zinc. A thin shaving of zinc, as we before noticed, will burn if held in the flame of a candle, without melting. The combustion of iron in oxygen gas is an interesting and beautiful experiment. See an account of the method of managing it in the chapter on Combustion.

§ All the metals except platina and gold will unite with sulphur by fusion. But the natural sulphurets contain more sulphur than the artificial ones; they must therefore have been formed by Nature by different means to those we employ in forming these compounds.

|| [illegible] of the metals have a very strong affinity for each other, as may be [illegible] experiment. Mercury will dissolve lead, bismuth, zinc, and [illegible] If a piece of lead and a piece of bismuth, each alloyed with [illegible] melted together, they form when cold a solid metallic mass;

pounds or alloys are formed extremely useful in a variety of arts, manufactures, and other requisites of life.

By what other means does Nature render these bodies subservient to our wants, and capable of ministering to our comfort and gratification?

Nature has furnished us with acids, whereby the most refractory metals may be dissolved* and purified, and rendered fit for a variety of purposes to which they could not otherwise be applied; and by combining them with oxygen we can invest them with *new* properties, and are enabled to employ them to promote the progress of the fine arts, by imitating the masterpieces of creation, in the production of artificial salt, spars, and gems, of every colour and of every shade†.

How does oxygen produce these changes in metals?

Different metals acquire different colours by their union with oxygen, and the same metal attains a different hue, according to the portion of oxygen combined with it‡; so that this wonderful substance seems destined not only to render us the most important services, but to embellish the works of creation, by the beautiful tints which it imparts to almost all subjects, whether of the animal, vegetable, or mineral kingdom.

You seem to think that the changes which metals undergo by their absorption of oxygen are the most surprising phenomena of nature:—can you recollect some other properties of oxygen, to serve as a comparison, and to elucidate its importance?

but from their affinity for mercury they have acquired so much fusibility that they will melt by the heat of boiling water. See note, page 221.

* The alchymists were in search of an universal *solvent* of all metals; but, as Mr. Davy has remarked, if such a solvent really existed, nothing would be so much dreaded by modern chymists. It would prevent the analysis of every mineral into which it entered, and would be like the fabled water of the Styx, which petrified every thing it touched. How different are the views of the scientific chymist to those of the ancient adepts, who concealed their knowledge with the greatest care, and appear to have had no other view but to surprise a gaping multitude!

† If phosphoric acid be united with silex by fusion, artificial precious stones may be prepared with the compound, which may be coloured to imitate any particular kind, by one or other of the metallic oxides.

‡ The oxide of iron is an eminent example of this change of colour. No less than seven distinct colours, besides a great variety of shades, are observed in minerals containing iron; and to the iron in most cases is the colour to be ascribed.

White in the somnite.
Black in the obsidian.
Green in the euclase.
Blue in the lazulite.
Red in the garnet and ruby.
Yellow in the topaz.
Brown in the tourmaline.

When I consider, in addition to its multiform effects upon metals*, that no animal can exist; no acid can be formed; no kind of combustion whatever can take place; nor even the most insignificant vegetable perform its proper functions, without the agency of this most astonishing substance, I cannot but exclaim—We want no further proofs to demonstrate, that the organization of the world has been effected by superlative wisdom and consummate goodness—attributes belonging to Him only, who has thus supplied our wants, and administered to our comforts, and even to our luxuries. Other instances might be enumerated in which oxygen is indispensably necessary: its importance is, however, too eminently conspicuous to be overlooked in the *formation of water*; every atom of which, whether we consider the ocean, lakes, rivers, and fountains, that pervade every corner of this material world, or the vapours of its atmosphere, all is made up of *three-fourths* of this single *simple* substance, OXYGEN.

* It is no unusual thing for the votaries of chymistry to call it a fascinating science. That it is the most useful of all sciences cannot be denied; nor can there be the least doubt that it has a strong tendency to enchant those who devote their attention to it. It serves as a powerful stimulus to youth, by occupying their time so satisfactorily to themselves, and rendering all low and unworthy pursuits truly detestable. But amidst the great variety of subjects which this science embraces, the changes which the metals undergo by their *absorption of oxygen* are perhaps more eminently calculated than any other of its departments, to give a relish for chymical pursuits, and to engage the young mind in the unremitted examination of the works of creation.

"The philosophic youth,
To NATURE's voice attends, from month to month,
And day to day, through the revolving year;
Admiring, sees her in her *every* shape;
Feels all her sweet emotions at his heart;
While TRUTH, divinely breaking on his mind,
Elates his being, and unfolds his powers."

THOMSON.

CHAPTER XI.

OF OXIDES.

WHAT is an oxide?

Any one or more of the simple substances, when united to a less quantity of oxygen than what is necessary to form an *acid*, is called an *oxide*.

What substances are capable of forming oxides?

The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxides by their union with oxygen*.

What minerals are convertible into oxides?

The metals are all capable of forming oxides†: so is sulphur, which is a peculiar substance, often found in combination with metals.

In what way do metals become united to oxygen?

* The oxides appear to range themselves into two classes. There are oxides which are permanently such, so long as they retain the oxygen which enters into their formation; and there are others which seem to possess only a kind of intermediate state between combustibles and acids, being convertible into acids by a further portion of oxygen. This will appear as we proceed.

† According to the old theory, metals were supposed to be oxidized by the loss of phlogiston; and when these oxides were reduced to a metallic state, it was imagined that they recovered their phlogiston from the carbonaceous matter employed in their reduction. Those persons who have not been in the habit of reading the works of the older chymists may understand them by attending to the following particulars: In most cases, all that is necessary is to substitute the word *oxygen* for *phlogiston*, with a slight inversion of the language. For the effects which they attributed to the combination of phlogiston appear to be due to the extrication of oxygen; and what they supposed to be owing to the loss of phlogiston were really occasioned by the absorption of oxygen.

There are several ways in which metallic oxides are formed, the chief of which are by the access of atmospheric air; by the decomposition of water; and by the decomposition of acids.

Will all metals become oxidized by exposure to the air?

No: gold, silver, and platina, cannot be oxidized, unless in a very high temperature; though iron, copper, and lead, will by long exposure to the air be oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

Are metals ever exposed to the air with the design of converting them into oxides?

The common red lead of the shops, which is a true oxide of lead, is made by melting that metal in ovens so constructed as to have a free access of atmospheric air*.

How is it known that the change of common lead to red lead is caused by the absorption of oxygen?

This is known by the increase of weight which the metal acquires during the operation; and because it may again be reduced to its metallic state by any combustible body that has a greater affinity for oxygen. By this de-oxidizement the metal will be reduced to its original weight†.

Do all metals increase in weight by being converted into oxides?

All metallic oxides weigh heavier than the original metal from which they were formed‡; but the different metals combine with different proportions of oxygen; and these proportions may be said to indicate the *capacity* of the several metals for this substance. Indeed some metals have so strong an attraction for oxygen, that they are capable of absorbing it from other metals, and becoming oxidized themselves thereby§.

* Some of the metallic *solutions* cannot be formed without atmospheric air. Thus, copper or lead placed in acetic acid, and excluded from the air, does not form any solution; but if the mixture be exposed to the air, oxygen is absorbed and the solution takes place. Berthollet.

† The following account of the manufactnre of red lead, from Watson's Chymical Essays, will be a satisfactory proof of this doctrine. In the manufactories of red lead in Derbyshire, the melted lead is exposed to atmospheric air; the surface soon becomes covered with a dusky pellicle; this pellicle being removed, another is formed; and thus, by removing the pellicle as fast as it forms, the greater part of the lead is changed into a yellowish green powder. This powder is then ground very fine in a mill, and, when washed and properly dried, is thrown back into the furnace, and by constant stirring for 48 hours, so as to expose every part to the action of the air, it becomes red lead, and is taken out for use. Twenty cwt of lead generally give 22 cwt. of red lead; so that 2 cwt. of oxygen is absorbed from the atmosphere during the process.

‡ This, as Mr. Henry has remarked, may be shown by keeping a given weight of iron wire red hot for some time in the bowl of a common tobacco-pipe.

§ Zi[illegible] [illegible]nposes a great number of salts and metallic solutions by its

What metals are oxidized by the decomposition of water?

Iron, zinc, tin, and antimony, decompose water, and become oxidized by the process. The rust which forms upon polished iron is a true oxide, occasioned by the iron decomposing the water in atmospheric air, and imbibing its oxygen. This metal, when heated, decomposes water with great rapidity*.

How do these metals operate in thus decomposing water?

This effect, like most of the operations of nature, depends on chymical affinity. These metals have a greater affinity for oxygen than oxygen has for hydrogen: the oxygen of the water, therefore, unites with the metal, to form a metallic oxide†, while the hydrogen, the other ingredient of the water, escapes in the form of gas.

Is it known what proportion of oxygen each metal requires, in order to its being converted to an oxide?

Most of the metals are capable of combining with different proportions of oxygen, according to the mode by which they are oxidized‡.

powerful attraction for oxygen, and precipitates the metal from them under a metallic form; or under that of oxides less oxidized than they were before. This may be exemplified by the experiment of the metallic tree, which has been attributed to Dr. Black. For the method of conducting it, consult any system of chymistry.

The pin-manufacturers whiten their pins on the same principle. They fill a pan with alternate layers of pins and grain tin, into which they pour a solution of super-tartrate of potash, and then boil the whole for four or five hours. In this process, the tartaric acid first dissolves the tin, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc, which enters into the composition of the *brass* wire of which the pins are formed.

* An increase of near 30 per cent. may be given to iron, by heating it red hot, and passing a continued stream of the vapour of water over it when in that state. This increase of weight is owing to its imbibing the oxygen of the water.

The metals which are capable of decomposing water effect it much sooner by means of heat than without. In this case, the caloric unites with the hydrogen of the water, and carries it off in hydrogen gas; while the oxygen, the other component part of water, unites with the metal. Hydrogen requires a very large portion of caloric to give it the gaseous form. This accounts for the necessity of heat when water is decomposed by means of some metals.

† See the account of an experiment, page 83, which explains the operation of metals in the decomposition of water.

‡ With respect to some metals, one dose of oxygen occasions the loss of their metallic splendour; a larger dose destroys that splendour entirely; and the proportion of oxygen may be increased so far as to give to the oxides an appearance altogether earthy. Bouillon La Grange. Some of the metals are capable of several degrees of oxidizement, producing oxides of different colours and possessing very different properties.

In the oxidizement of metals by acids, though there be no oxygen gas sensibly present by which it is effected, oxygen exists in the acids, also in

In what manner are acids used to oxidize metals?

Many instances of this mode of forming metallic oxides might be adduced. Those which are most known are, perhaps, the common white lead, which is made by exposing sheet lead to the fumes of acetous acid*, and the oxide of tin, and of bismuth; which latter are formed by the nitric acid.

What are the properties of metallic oxides?

They are in general friable and pulverulent; are heavier than the primitive metal; and with the different acids, form metallic salts†.

Is it necessary to oxidize those metals which are intended to be formed into metallic salts?

the water with which the acids are diluted; and the effect is owing to the passage of a portion of oxygen from one of these substances to the metal; and the increase in weight which the metal acquires is always equal to the weight of the oxygen absorbed. Whenever a metallic oxide dissolves in an acid, it causes the acid properties to disappear exactly as if an alkali had been employed; and saturates corresponding quantities of the different acids. *Berthollet.*

* The manufacture of white lead is conducted in the following manner: A quantity of earthen crucibles, holding from 3 to 6 quarts each, and nearly filled with vinegar, are placed in hot beds of tan; upon these crucibles thin sheets of lead, rolled up in coils, are placed, one coil over each crucible. The heat of the bed occasions the vinegar to rise in vapour, which attaches itself to the lead and oxidizes its surface to a considerable depth. At a certain time the oxide which has been thus formed is scraped off, and the coils of lead replaced, which soon become oxidized throughout. This oxide, which contains a portion of carbonic acid, is afterwards *washed*, and ground for sale. See Additional Notes. No. xxviii; also Mr. Hume's Observations, in the Medical and Physical Journal for March 1805.

† The metallic oxides will combine with the alkalies, and with some of the earths similar to the acids. Hence originated the terms plumbate of potash, plumbate of lime, argentate of ammonia, &c. Berthollet. These terms, however, are certainly improper.

‡ The nature of the combination of oxygen with a metal, the subsequent solution of the metal in an acid, and its revivification, may be shown in a satisfactory manner by the following process: Take a quantity of copper filings, boil them in concentrated sulphuric acid (common oil of vitriol) with a small portion of nitric acid, and when the copper is dissolved dilute the solution with water, and set it aside to crystallize. The crystals will be the true sulphate of copper and will exemplify the formation of a metallic salt. Then dissolve these crystals in a little water; and if the polished blade of a knife be immersed in the solution, the copper will be revived, and appear of its natural colour upon the knife. The oxygen, having a greater affinity for the iron than the copper, passes to the iron, by which the copper becomes de-oxidized, and consequently insoluble in the acid; it therefore precipitates itself from the solution, and attaches itself to the knife in a metallic form. In the formation of sulphate of copper, the oxidizement of the metal, and its solution in the acid, seem to be only one operation; but the metal is undoubtedly first oxidized by the oxygen of the nitric acid, and *then* becomes soluble.

Most of the metallic oxides are poisonous, especially those which retain oxygen slightly.

All metals are incapable of dissolving in acids, until they are combined with oxygen*.

Is there any instance of the stronger acids being made use of by manufacturers to dissolve metals ?

Yes : the manufacturers of sulphate of copper boil the oxide of copper in strong sulphuric acid, and dissolve it by that operation†.

What other instances are there of manufacturers using the mineral acids for dissolving metals ?

Silver is frequently dissolved in nitrous acid, by the refiners in the business of parting‡; gold is dissolved in nitro-muriatic acid, for painting china; and the dyers use large quantities of tin dissolved in a peculiar acid prepared for that purpose§.

Is it possible to recover metals which have been dissolved in acids ?

The attraction of the different metals for oxygen is so various, that several of them, when dissolved, may be precipitated even in a metallic form, by the addition of metals that have a greater affinity to oxygen than the dissolved metal‖.

What is the usual mode of reducing other metallic oxides ?

Charcoal is the agent usually employed, on account of its superior affinity for oxygen¶.

Are you acquainted with any other agent which is equal to the deoxidizement of a metal ?

* It is not only true that all metals must be oxidized before they can be dissolved in acids, but they must contain a certain proportion of oxygen, which proportion varies according to the metal employed. On the other hand, if a metal has combined with more oxygen than the necessary proportion, it will precipitate itself from the acid, and be incapable of forming a salt. The dyers are often perplexed by the operation of this principle. In making their solutions of tin, if they add the tin to the acid too hastily, or in too large quantities, the tin becomes, by the violent action of the acid, more oxidized than it ought to be, and precipitates itself instead of remaining in the solution. In some metallic solutions it is necessary to add a third substance, for the purpose of depriving the metallic oxide of part of its oxygen, in order to prevent a precipitation.

† This is common blue vitriol. The mode of its manufacture may be collected from the former note.

‡ For an account of this business, consult Lewis's Commerce of the Arts.

§ It is supposed that some hundred tons of tin are annually used in this way by the dyers of these kingdoms.

‖ This is exemplified by the refiners in their operations. When the silver is dissolved in aqua-fortis, they recover it by placing plates of copper in the solution. The copper absorbs oxygen from the silver, and the latter is precipitated in a metallic state. All metals have the powers of de-oxidizing gold and silver; copper will take oxygen from mercury; and iron will reduce an oxide of copper. The degree of attraction for oxygen, which the different metals possess, seems to be in the following order :—manganese, zinc, iron, tin, copper, mercury, silver, gold.

¶ The usual mode of procedure is to mix a quantity of charcoal with

Yes: some metals have so loose an union with oxygen, that even light* will separate it, and reduce the oxide to its original metallic state. Hydrogen gas will effect the same purpose, when assisted by heat†.

What oxides are there besides metallic oxides?

We are acquainted with an oxide of each of the simple combustibles‡, sulphur, phosphorus, and hydrogen; with two oxides of carbon, the other simple combustible; and with two of nitrogen.

metallic oxide, and subject the mixture to an intense heat in crucibles. The oxygen combines with the charcoal and with a portion of caloric, and goes off in carbonic acid gas; the metal then falls to the bottom of the crucible in a button.

The reduction of metallic oxides, by mixing them with charcoal powder, and submitting them to the action of fire, probably gave rise to the fable of the Phœnix, which was a favourite emblem with the old chymists:

> For, when Arabia's bird, by age opprest,
> Consumes delighted on his spicy nest,
> A filial Phœnix from his ashes springs,
> Crown'd with a star; on renovated wings
> Ascends exulting from his funeral flame,
> And soars and shines, another and the same.
>
> DARWIN.

The old chymists had certainly an idea that combustion cannot destroy the matter on which it operates. I have seen an old engraving of sundry chymical apparatus, with a Phœnix in the midst of its flames, with this superscription.—

Naturæ regna instar Phœnicis per ignem reviviscunt.

Of all known substances, carbon and hydrogen have the strongest attraction for oxygen. This accounts for their efficiency in de-oxidizing metallic oxides. Muriatic acid has the property of partially de-oxidizing several of the metallic oxides. It has a greater affinity for oxygen than any other acid.

* Oxygen gas is composed of oxygen, caloric, and *light*. Without a chymical union with light it would not be in a state of gas. Hence light, when it comes in contact with the oxide of gold, silver, &c. puts the oxygen of the metal in a condition to unite with itself, and with the caloric it finds in atmospheric air, or in any neighbouring body. As it unites with these substances, viz. light and caloric, it leaves the metal, and takes the state of oxygen gas. The oxide of mercury requires much light as well as heat to reduce it. This property of light, by which it de-oxidizes metallic oxides, accounts for the necessity there is of keeping some metallic colours in well stopped impervious vessels. Respecting the nature of light, see Additional Notes, No. XXI.

† If the red oxide of lead be put into a receiver of hydrogen gas, and the oxide be heated by means of a glass lens, the oxygen of the metal will combine with the hydrogen to form water, and the metal will be completely re-

‡ With the exception of water, all the products arising from the union of simple combustibles with oxygen are either oxides or acids.

What is the origin of the oxide of sulphur?

This oxide is formed by keeping sulphur melted* for some time in an open vessel, whereby it absorbs oxygen from the surrounding atmosphere†.

What is the origin of the oxide of phosphorus?

If phosphorus be not preserved entirely from the access of air and light, it soon becomes first white, and then of a dark brown colour, by its union with oxygen. In this state it is *oxide* of phosphorus‡.

What is the nature of the oxide of hydrogen?

Hydrogen differs from the other three simple combustibles in being capable of combining only with one dose of oxygen; whereas *they* form acids as well as oxides. The combination of oxygen with hydrogen produces water§.

What is the nature of the oxides of carbon?

The first degree oxidizement of carbon produces *carbonous* oxide, or charcoal‖: a further degree of oxidizement gives it a gaseous form, and produces *carbonic acid?*

How is carbonic oxide prepared?

Carbonic oxide, which was one of the last discoveries of Dr. Priestley, is procured by heating charcoal with metallic oxides, or earthy carbonates; by which means the charcoal absorbs sufficient oxygen to give it a gaseous form.

What is the difference in the composition of carbonic oxide *and carbonic* acid?

Carbonic *oxide* contains 60, and carbonic *acid* 82 per cent, of oxygen¶.

What are the properties of carbonic oxide?

Carbonic oxide is invisible and elastic like other gases; its specific gravity is somewhat less than that of atmospheric air; it

* By this operation sulphur acquires a permanent red colour. It is used in this state for taking off impressions from seals and medals.

† According to a late analysis of Dr. Thomson, the oxide of sulphur contains 97.6 sulphur, and 2.4 oxygen. See his paper on this subject in Nicholson's Journal, 8vo. vol. vi. 92.

‡ Phosphorus, when newly prepared, always contains some oxide of phosphorus mixed with it; but this may be easily separated by plunging the mass into water heated to about 190. The phosphorus melts, while the oxide remains unchanged, and swims upon the surface of the melted phosphorus. Dr. Thomson, i. 44, second edition.

§ For the nature and properties of water, see Chap. iv. page 78.

‖ Charcoal is composed of about 64 carbon and 36 parts oxygen; but it generally contains also a small portion of hydrogen. For the properties of charcoal consult Chap. ix. page 176.

¶ Carbonic oxide is composed of 60 oxygen, and 40 carbon. Carbonic acid 82 oxygen, and 18 carbon.

is highly combustible*; but it is a gas that will not itself support combustion; neither is it fit for animal respiration†.

What are the oxides of nitrogen?

The first degree of oxidizement produces *nitrous oxide*; a further portion of oxygen forms *nitric* oxide. Both these oxides are in the state of gas.

What is the origin of nitrous *oxide; and how is it procured?*

Nitrous oxide is another of the gases discovered by Dr. Priestley‡. It is readily procured by exposing crystals of nitrate of ammonia in a retort, to the heat of a lamp§; by which means the ammoniacal salt is decomposed, and this gas evolved.

What are the properties of nitrous oxide?

This gas bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air; is respirable for a short time‖; is absorbed by water; and is capable of forming salts of a peculiar nature by its combination with alkalies. Its spec. grav. is much greater than that of common air.

What is the origin of nitric *oxide; and how is it procured?*

Nitric oxide, or nitrous gas as it has usually been called, was discovered also by Dr. Priestley, during some of his first experi-

* Carbonic oxide in contact with oxygen burns with a lambent blue flame; but it burns with more rapidity and brilliancy when mixed with oxygen gas.

† According to some French Chymists, birds drop down dead immediately on being put into this gas. These chymists attempted to breathe it themselves; on whom it produced giddiness and faintness. Ann. de Chim. xxxix. 56.

‡ Priestley discovered this gas about the year 1776, and called it *dephlogisticated* nitrous gas. For further information respecting its properties consult Mr. Davy's Researches. Mr. Davy investigated it with great care, and pointed out its nature and properties.

§ The heat should not be less than 340°, nor above 400°. One pound of dry nitrate of ammonia, well decomposed, will produce rather more than four cubic feet of air.

Nitrous oxide, or the gaseous oxide of nitrogen, as it is sometimes called, is composed of 63 nitrogen, and 37 oxygen.

‖ Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion, and a propensity to leaping and running; on others involuntary fits of laughter; and in all high spirits, and the most exquisitely pleasurable sensations, without any subsequent feelings of debility. When Mr. Robert Southey, the poet, inhaled it, he declared that it produced in him sensations perfectly new and delightful; and that he imagined that his taste and smell were more acute than usual for several hours afterwards. In a poetical rhapsody he remarked, that he supposed the atmosphere of the highest of all possible heavens must be composed of this gas. See Davy's Researches, and Nicholson's Journal, vol. iii. 410. 446.

ments on air*. It is procured by digesting copper or mercury in diluted nitrous acid, and collecting the gas which rises during the solution.

What are the properties of nitric oxide?

Nitric oxide is an invisible gas, which assumes an orange colour whenever it comes in contact with atmospheric or any other air that contains oxygen†. It produces suffocation in those animals who attempt to breathe it, though some substances will burn in it‡. Its specific gravity is somewhat more than that of common air.

What compounds are formed by means of nitric oxide?

Nitric oxide gas, when mixed with oxygen gas, forms nitric *acid*. The aqua-fortis of commerce owes its colour to this gas.

What other oxides are you acquainted with?

The red part of the blood of animals is an oxide; and sugar is a vegetable oxide. Moreover, oils§, butter, and dryed salt meats, become rancid by absorbing oxygen from the atmosphere; so that oxygen not only performs for us an infinite number of valuable and important offices, but appears to be one of the grand agents of decomposition and destruction‖.

* This gas was used by Priestley for purposes of eudiometry. The first eudiometer was made in consequence of Dr. Priestley's discovery, that when nitrous gas is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, in consequence of the combination of the gas with the oxygen of the air, and the absorption of the nitric acid, thus formed, by the water. Whenever nitrous gas is thus mixed with atmospheric air, the diminution will be in proportion to the quantity of the oxygen; of course this gas will always indicate the measure of oxygen present in any portion of air submitted to trial. In consequence of some inconveniencies attending the use of this eudiometer, others have been invented by Scheele, De Marti, Humboldt, Seguin, Berthollet, and Davy. An account of their different processes may be seen in Dr. Thomson's Chymistry.

† Nitric oxide is composed of 57 oxygen, and 43 nitrogen, by weight. Nitric *acid* is composed of 75 oxygen, and 25 nitrogen.

‡ If phosphorus be previously inflamed, it will continue to burn in this gas with as much splendour as in oxygen gas.

Dr. Priestley found, by experiment, that 100 measures of nitric acid, of a moderate strength, absorbed in two days 90 of nitrous gas: that when about 7 parts were absorbed, the acid assumed an orange colour, when 18 parts were absorbed a green colour, and when the 90 were combined it became red and fuming.

§ Seed oils are sometimes oxidized artificially for the purposes of painting. Linseed oil is thus boiled with the red oxide of lead. In this operation, the oxygen leaves the metal and combines with the oil, imparting to it the property of drying quickly. Oil thus prepared is called *drying* oil.

‖ All organized beings, whether vegetable or animal, possess the materials of which they are composed only for a limited time: life itself is a boon which is only *lent*, to serve the purposes of infinite beneficence. At the proper period, *oxygen*, or some other powerful agent, effects the decom-

position of the curious fabric, and sets all the elementary particles at liberty, to form other equally perfect and complicated existencies*.

> Which *thus*, alternating with death, fulfil
> The silent mandates of the ALMIGHTY's will;
> Whose hand, unseen, the works of nature dooms,
> By laws unknown,—WHO GIVES AND WHO RESUMES.
>
> DARWIN.

* See Additional Notes, No. V.

CHAPTER XII.

OF COMBUSTION.

WHAT is combustion?

Combustion* is a process by which combustible bodies decompose oxygen gas, absorb its base†, and suffer its caloric to escape in the state of sensible heat.

Are all substances capable of being burnt?

No: some substances are combustible‡, others are incombustible.

* Lavoisier and other French chymists defined combustion to be the combination of any body with oxygen. This definition, however, has very properly been objected to; for there are many instances of oxygen combining with a body *without* producing combustion. Indeed, this union is sometimes effected when no combustion can possibly take place. Oxygen often combines with bodies without any extrication of heat or light; but we never, in common language, give the name of combustion to any operation in which heat and light are not liberated.

† To render the explanation of this process more conspicuous, it may be said, that oxygen exists in the state of gas in atmospheric air; that when a combustible is heated to a certain degree, it possesses such an attraction for oxygen, that it takes it from the air and fixes it in a solid form; while the light and caloric, the solvents which gave it the gaseous state, escape and diffuse themselves among the surrounding bodies.

‡ The term combustible is applied to every body that is capable of being [illegible] in o[illegible]s, and, consequently, of uniting with its base.

How are combustible bodies classed by chymists?

Into simple combustibles, compound combustibles, and combustible oxides*.

What do you mean by SIMPLE combustibles?

Those combustible substances which have resisted every attempt to decompose them, are called simple combustibles†.

Endeavour to enumerate the simple combustibles?

The simple combustibles with which we are acquainted are: hydrogen, sulphur, phosphorus, carbon, and all the metals, except gold, silver, and mercury‡.

What are COMPOUND combustibles?

Compound combustibles are all such as are formed by the union of two or more of the simple combustibles§. Common coal is an instance of this combination‖.

What substances are there which are incombustible?

We are acquainted with thirteen incombustible substances, viz.

* The combustible oxides consist of combinations of the combustible bodies, which have not undergone combustion, or their compounds, with oxygen. This class of bodies is very numerous, as it includes the greater part of animal and vegetable substances. The great combustibility of combustible oxides is probably owing to the weaker affinity by which their particles are united. Hence, they are more easily separated than homogeneous particles, and of course combine more readily with oxygen. Those simple combustibles which melt easily, or which are in the state of elastic fluids, are also very combustible, because the cohesion between their particles is easily overcome. Dr. Thomson, in Nicholson's Journal for 1802.

† For an account of the nature and properties of the simple combustibles, see Chap. ix. page 170.

‡ We may be satisfied that metals are really combustible, by repeating the following simple and beautiful experiment of Dr. Ingenhousz:—"Twist a small iron wire into the form of a corkscrew, by rolling it round a small stick: fix one end of it into a cork (which will fit a glass jar previously filled with oxygen gas), and lap round the other end a small bit of cotton thread dipped in melted tallow. Set fire to the cotton, and plunge it while burning into the jar of oxygen gas. The wire will take fire from the cotton, burn with great brilliancy, throwing out very vivid sparks in all directions. During the combustion, the iron combines with the oxygen which was in the jar, and is converted into an oxide, with an augmentation in weight of 35 per cent." Mr. Accum says, that a thick piece of iron or steel, such as a file, may be burned in oxygen gas, if it be made very sharp-pointed, and a small piece of wood be stuck upon its extremity and set fire to previous to its being immersed in the gas. The method of suspending the metal in the jar may be seen in plate 4, fig. 17, of Lavoisier's Elements.

§ The compound combustibles are arranged by Dr. Thomson under the five following heads: 1st, sulphurets; 2d, phosphurets; 3d, carburets; 4th, alloys; 5th, sulphuretted, phosphuretted, and carburetted hydrogen.

‖ Hydrogen and carbon, intimately united in the capillary tubes of vegetables, form bitumens, oils, and resins, which are compound combustibles. See Additional Notes, No. XXXIX.

...rogen*, the three alkalies, and the nine earths†.

What is the nature *of combustion*‡?

Combustion appears to be a double decomposition§, in which the combustible and the supporter of combustion divide themselves each into two portions, which combine in pairs; the one forming the product, the other the fire which escapes‖.

What do you mean by SUPPORTERS *of combustion?*

The substances which are called supporters of combustion are not of themselves combustible, but are necessary to the process; that is, no combustion can ever take place without one or other of the supporters of combustion being present¶.

* Perhaps nitrogen might be called a *combustible* body, as by means of electricity it combines with the base of oxygen gas, forming nitrous acid.

† Some of the alkalies and earths possess certain properties in common with combustibles, and are capable of exhibiting phenomena somewhat analogous to combustion. These have been described under the title of *semi-combustion*; but for particulars I must refer the reader to Dr. Thomson's Theory of Combustion, in Nicholson's Journal for 1802.

‡ To the old chymists the process of combustion was quite inexplicable; its nature indeed was not at all understood till within these thirty years. It is now known to be merely a play of affinities between oxygen, light, caloric, and the base of the combustible body.

§ Dr. Thomson's account of combustion will convey a clear idea of this natural phenomenon to the reader.—"When a stone, or brick, is heated, it undergoes no change except an augmentation of temperature; and when left to itself it soon cools again, and becomes as at first. But with combustible bodies the case is very different. When heated to a certain degree in the open air, they suddenly become much hotter of themselves, continue for a considerable time intensely hot, sending out a copious stream of caloric and light. This emission after a certain period begins to diminish; and at last ceases altogether. The combustible body has now undergone a most complete change, it is converted into a substance possessing very different properties, and no longer capable of combustion. The product is incombustible, because its base being already saturated with oxygen cannot combine with any more. M. Lavoisier fully established the existence of this general law—that 'in every case of combustion oxygen combines with the burning body.' Oxygen does not combine with a combustible body till its temperature is raised; but when a combustible body is raised to a certain temperature, it begins to combine with the oxygen of the atmosphere, and this oxygen during its combination lets go the caloric and light with which it was combined while in its gaseous state." Dr. Thomson.

‖ The component parts of the oxygen which is furnished by the supporters of combustion are two, viz. *oxygen* and *caloric*: the component parts of all combustibles are likewise two, viz. the *base* and *light*. If the two first are called No. 1 and 2; and the two latter No. 3 and 4, the product of combustion will be formed by the union of No. 1 and 3, and the compound, which we call fire, will arise from the combination of No. 2 and 4. Dr. Crichton, I believe, was the first chymist who gave this view of combustion. In his public lectures he has long elucidated the theory, by many appropriate experiments.

¶ For a further elucidation of this subject, consult Dr. Thomson's Essay on Combustion in Mr. Nicholson's Philosophical Journal for 1802.

What substances are deemed supporters of combustion?

There are only seven known supporters of combustion, viz. oxygen gas*, atmospheric air, nitrous oxide, nitric oxide, nitric acid†, oxygenized muriatic acid, and hyper-oxygenized muriatic acid‡.

What is it that imparts to these various bodies the peculiar property of supporting combustion?

The principle common to all these substances is OXYGEN; it is therefore to oxygen alone§ that they are indebted for this property.

Is it known how oxygen supports combustion?

The agency of oxygen in combustion is attributable to its affinity ‖ for combustible bodies. For whenever such bodies are ignited in circumstances favourable to combustion they absorb oxygen from the atmospheric air, or other contiguous substances, till the combustible is converted to an incombustible body.

* If oxygen gas be forced out of a bladder, or a gasometer, upon a piece of ignited charcoal, the combustion will be so much increased, that the light thrown off will be too vivid for the eye to endure.

† If nitric acid be mixed with about half its weight of concentrated sulphuric acid, and a little oil of turpentine be poured into the mixture, the whole will immediately burst into flame. In this experiment it is the oxygen of the nitric acid which promotes the combustion.

‡ To the above list of supporters might be added *water*; for it is well known that water in many cases promotes and accelerates combustion. It appears that the ancients were acquainted with this property of water: hence the invention of the æolipyle, which was much in use formerly. Dr. Plott, in page 433 of his History of Staffordshire, mentions a curious instance of the employment of this instrument. He says, that the lord of the manor of Effington is bound by his tenure to drive a domestic fowl every new-year's-day three times round the fire in the hall of the lord of Hilton, while Jack of Hilton (a brazen figure having the structure of an æolipyle) blows the fire. I believe this grotesque figure is still preserved at Hilton; a drawing of it may be seen in the thirty-third plate of Plott's Staffordshire. The Heathen priesthood employed this instrument in working sham miracles. Some of the ancient Saxon and German idols were of this construction. See Vocabulary, article *Æolipyle*.

§ As oxygen gas contains that caloric which is liberated during combustion, we have reason to suppose that all the supporters of combustion contain caloric combined with their oxygen, as an essential ingredient in their composition.

‖ Combustion, like all other chymical processes, may be explained by the laws of chymical affinity. The combustible having a greater affinity to oxygen than oxygen has to caloric, the oxygen gas is decomposed, and its oxygen combines with the ignited body, while its caloric becoming free produces the heat which is diffused among the surrounding bodies. As the oxygen unites with the combustible, it becomes more dense than it was when in the state of gas, consequently it has less capacity for caloric than it had; a portion of it therefore must be given out before the oxygen can combine with the new substance that attracts it from its former combination.

From whence proceeds the heat which we observe during combustion?

In general, the heat produced by combustion arises from the oxygen gas of the atmosphere*; for, as the oxygen combines with the combustible body, it disengages the caloric which it held when in the state of atmospheric air.

Can you explain this operation with more precision?

The act of combustion effects a real analysis of atmospheric air; for while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction.

Does this account for the long continued heat which we experience in every common combustion?

Whenever we burn a combustible body in order to procure heat, a continued stream of atmospheric air flows towards the fire-place† to occupy the vacancy left by the air that has undergone decomposition, and which in its turn becomes decomposed also‡. Hence a supply of caloric is furnished, without intermission, till the whole of the combustible is saturated with oxygen.

What other effects are produced by combustion?

As the combustible burns, LIGHT is disengaged, and the more subtile parts of the combustible, now converted by caloric into gas, are dissipated in that state§. When the combustion is over, nothing remains but the earthy parts of the combustible, and

* Though every case of combustion requires that heat should be evolved, yet this process proceeds very differently in different circumstances. Hence the terms *ignition*, *inflammation*, *detonation*, &c.

† On some parts of the continent their rooms are warmed by stoves which have ash-pits without, so that the combustion is kept up by air which has no connection with the air of the room. The consequence of this is, that the air of the room is not contaminated, and the persons who occupy it are not subject to the inconvenience of those cold draughts of air which render some of our rooms that have large fire-places dangerous and unhealthy.

‡ The Argand's lamp is constructed upon this principle, that a current of air hastens combustion; for in consequence of this perpetual supply of oxygen the air is renewed every moment, and produces heat sufficient to burn the smoke as it is formed. The smoke which arises from a common fire is chiefly water in the state of vapour, with a mixture of carburetted hydrogen and bituminous substances; part of which water comes from the moisture of the fuel; the other part is formed during combustion, by the union of the hydrogen of the combustible with the oxygen of the atmosphere. What goes forward in a common fire-place would furnish an intelligent parent with matter for several interesting conversations, which could not fail to [illegible]e the curiosity and engage the attention of his pupil. See Add. Notes, [illegible]cvi.

§ [illegible]art of the caloric which is furnished by the supporters of combustion [illegible]lly combines with part of the combustible, and converts it into gas, [illegible] been beautifully expressed by Dr. Darwin:—

that portion which is converted to an oxide or an acid by the process*.

From whence proceeds the light which you say is disengaged during combustion?

It is now generally supposed that the light and flame which appear during this process proceed from the combustible body†: though some chymists imagine that the light comes in part from the decomposition of atmospheric air‡.

What is the origin *of light?*

Light, which is an extremely attenuated fluid matter, is constantly transmitted from the sun to the earth§. It is also found

Thus heat from chymic dissolution springs,
And gives to matter its eccentric wings;
With strong repulsion parts the exploding mass,
Melts into lymph, or kindles into gas.

* The products of combustion are always either *water*, an *oxide*, or an *acid*.

† If the light arose from the decomposition of oxygen gas, those combustibles which decompose most oxygen gas would give out most light; but this is not the case. Hydrogen in burning combines with more oxygen than any other body, and gives out more heat; yet the light is barely perceptible. Several instances might be adduced, in which the quantity of oxygen combining with the combustible, during this process, is greatest where the light is smallest. See Add. Notes, No. xlii. and xliii.

"That a great part of the light comes from the combustible, is evident from the colour of the light generally varying according to the nature of the combustible. Carbonic acid burns with a blue flame, carburetted hydrogen with a white, charcoal with a red, and sulphur with blue or violet." Dr. Thomson. That lime contains light is well known. If quick lime be slacked in the dark the liberation of light will be very evident. That light is a real substance, and can become concentrated in bodies, is evident from the properties of phosphorus. But it may be satisfactorily shown by shutting a person up in a dark room, and directing him to put one of his hands out for a short time into the sun's rays, and then to draw it back into the dark room, when he will be able to see that hand distinctly, and not the other. See Add. Notes, No. xxiv.

‡ The following fact seems to prove that atmospheric air contains light. Some time ago a soldier in the French army found that heat was produced by the condensation of the air in an air-gun. The experiment has lately been repeated before the National Institute. If the air be very rapidly compressed, heat is disengaged by the first stroke of the piston, sufficient to set fire to a piece of fungus match placed within the pump. If the end of the pump be furnished with a glass lens which admits of the inside being seen, at the first stroke of the piston a ray of *vivid brilliant light* will be perceived. See Note, page 83—84.

§ Light is transmitted to us from the sun, accompanied with caloric, in little more than eight minutes, which is a velocity almost equal to 200,000 miles in a second of time; but the rays of light and the rays of caloric are distinct from each other. It has been demonstrated that some rays from the sun produce heat, which have no power of communicating light. For a further elucidation of this subject see a paper by Dr. Herschel in the Phi-

combined with several terrestrial substances*.

What is the nature of light?

Light is a peculiar substance, the nature of which is little understood; but it possesses several very singular and striking properties†.

[illegible] Transactions, and an account of the experiments of Sir Henry [illegible] in the first volume of the Journals of the Royal Institution. [illegible] will appear truly astonishing, when we consider that a [illegible] moving with the same velocity that it acquires when first [illegible], would be more than thirty years in arriving at this [illegible]

[illegible] of entering into bodies, and of being afterwards extri[illegible] [illegible]ration. It also combines with them, and forms one [illegible] parts. On this subject consult Dr. Hulme's paper in [illegible] Transactions for 1800 and 1801; Dr. Herschel's paper in [illegible] volumes, and Dr. Wollaston's in the volume for 1802; [illegible] interesting. See also Mr. Henry's observations in [illegible] the Manchester Memoirs. From the following beautiful [illegible] on Light, there is some reason to imagine, that even in [illegible] was entertained of light being latent in bodies:—

> Hail, holy light! offspring of Heaven first born,
> [illegible] Eternal co-eternal beam,
> [illegible] essence of bright essence increate—
> [illegible] who shall tell? Before the sun,
> [illegible] Heavens thou wert; and at the voice
> [illegible] with a mantle didst invest
> [illegible] world of waters dark and deep.

[illegible] light to be a substance consisting of small [illegible] from luminous bodies, moving in *straight* [illegible] by passing from them and entering the [illegible] seems to [illegible] all the known properties [illegible] reflection, refraction, &c. of its rays, may [illegible] System of Chymical Knowledge, and [illegible], in the Philosophical

[illegible] rays of different colours. [illegible] another, while they reflect the [illegible] bodies. A red body, for [illegible] the rest. A white body reflects [illegible], on the contrary, absorbs [illegible] "that if light had [illegible] been of one uniform colour; [illegible] variety of colours which is [illegible] of objects; which adds so [illegible] the stock of our innocent

[illegible] See Notes, No. xliv. It also [illegible] the metallic oxides, by com[illegible] wings to fly off in the

[illegible] absorbing light and giving it

Is the presence of atmospheric air necessary to combustion?

Combustion cannot take place in a vacuum; no combustible body can burn without atmospheric air, or at least without oxygen, which is a component part of atmospheric air*.

In what do combustible bodies differ from each other?

Combustible bodies differ from each other principally in the rapidity with which they absorb oxygen, and in the proportion of it which they† can take up, to form the new compound.

What is the effect of these properties in the act of combustion?

The greater the portion of oxygen gas which any combustible body is capable of decomposing, the greater will be the heat which is produced during combustion.

How is it known that oxygen unites with the combustible body in the act of burning?

If a combustible substance be burnt in a sufficient quantity of vital air in a close vessel, and the product preserved, the whole will be found to be increased in weight‡ exactly in proportion to the vital air consumed; and the combustible body will then have become incombustible§.

What is the cause of a body becoming thus incombustible?

Because when a body is fully burnt it is saturated with oxygen; at least as far as combustion can saturate it; it therefore cannot combine with any more: but some bodies may be rendered com-

"Sweet child of stillness, midst the awful calm
Of pausing nature thou art pleas'd to dwell,
In happy silence to enjoy thy balm,
And shed through life a lustre round thy cell."

Dr. WALCOTT.

In the Asiatic Annual Register for 1802, we are told that there is a sparrow of Hindostan which has the instinct to light up its nest in the night-time with glow-worms, which it collects for this purpose; and that it attaches them to the inside of its nest by means of a tenacious kind of clay. See Add. Notes, No. xli.

* This may be demonstrated by placing a lighted candle under a glass jar, inverted upon a plate of water. It will be seen that the candle will go out as soon as it has consumed all the oxygen contained in the included air.

† Almost all the simple substances are capable of combining with 3 doses of oxygen. Thus sulphur forms oxide of sulphur, sulphurous acid, and sulphuric acid. Phosphorus forms oxide of phosphorus, phosphorous acid, and phosphoric acid. Carbon forms carbonous oxide carbonic oxide, and carbonic acid. When these simple combustibles are united, the combinations are known by names ending in *uret*, as sulphuret of phosphorus, phosphuret of sulphur, &c. Dr. Thomson.

‡ Phosphorus is an eminent instance of this increase by combustion. If an ounce of phosphorus be properly inflamed, it will produce at least one ounce and a half of solid phosphoric acid.

§ A series of curious experiments of this kind may be seen in Lavoisier's Chymical Elements.

bustible *again*, by depriving them of the oxygen which they absorbed in their former combustion*.

In the decomposition of atmospheric air by combustion, what becomes of the nitrogen gas?

As the oxygen becomes fixed in the combustible body, its caloric is disengaged; part of which combines with the nitrogen, and carries it off in the form of rarefied nitrogen gas.

What chymical name is given to burnt bodies?

Such substances are said to be *oxygenized*, or *oxidized*; that is, changed into acids, or oxides.

Does the oxygen become fixed in all combustible bodies when burnt?

It is a characteristic property of the combustible body to form a chymical combination with the oxygen, which is furnished by the supporters of combustion. The oxygen acquires such density by this process, that it is often extremely difficult to separate it again†.

Is it possible to separate entirely the oxygen from burnt bodies?

Yes: bodies may be deoxidized in various ways‡; and in some cases the oxygen may be transferred from the burnt body to a fresh combustible body, and be made the means of producing a fresh combustion§; or it may in many cases be completely sepa-

* "This view of combustion authorizes us to divide almost all the productions of nature into two grand classes; one of *combustible* bodies, the other of bodies already *burnt*; in the masses and action of the former we discern the causes of inflammable meteors, the perpetual alteration of the surface of the earth, volcanoes, &c.; in the existence of the latter we perceive the source of the number and diversity of acids, saline compounds, oxides, and metallic salts, which vary in a thousand ways the appearance of ores, &c." Fourcroy.

† When oil is burnt in an Argand's lamp, its carbon unites with the oxygen of the atmosphere, and forms carbonic acid gas; while its hydrogen unites with another portion of oxygen, and forms water. Every 100 ounces of oil thus burnt produce [illegible] ounces of water. In these products of combustion the oxygen is more intimately combined than it was with caloric in the gaseous state. Hence we see what a beautiful series of changes and modifications the elements of matter are destined to undergo, and how admirably Nature has provided for the preservation of all her productions.

That the combustion of alcohol produced water was known in the time of Boerhaave. By presenting a cold vessel to the flame of alcohol he collected water without taste or smell, and in every respect like distilled water.

‡ Water is a product of combustion, whose base is hydrogen, the most combustible substance we are acquainted with. To restore the combustibility of the hydrogen, we have only to abstract its oxygen; which may readily be done, by mixing iron or zinc filings, and sulphuric acid with the water; the metal becomes oxidized, and the hydrogen gas is evolved as combustible as ever.

§ Iron, zinc, antimony, and arsenic, will burn with flame when heated with oxide of mercury. During the operation they attract the oxygen from the mercury, and absorb it in a more solid form. By this process the com-

rated, and shown in its primitive or gaseous state*.

What part of bodies is it which is destroyed by combustion?

No part that we know of. We have reason to think that every particle of matter is indestructible, and that the process of combustion † merely decomposes the body, and sets its several component parts at liberty to separate from each other, and to form new and varied combinations‡.

What is the natural inference from this interesting fact?

The natural conclusion is, that nothing less than consummate wisdom could have devised so beautiful a system, and that nothing short of infinite power could have so modified matter as to subject it to the operation of such laws—laws that effect so many desirable purposes, and at the same time so effectually prevent the destruction of those elementary principles which are actually essential to the preservation of the world§.

bustible property of the mercury is restored to it. Before this, it was an incombustible substance, rendered so by its union with oxygen, and the loss of its light.

* This is frequently done for the purpose of procuring oxygen gas. The oxides of manganese, or the oxides of mercury, are exposed to a proper degree of heat, and the gas received in a proper apparatus as it is extricated.

† The following concise account of the theory of combustion I copy from Berthollet, as it explains this process in a way too plain to be misunderstood; "When bodies are burnt, none of their principles are destroyed; they had previously formed together one kind of compound, and they now separate from each other, at the high temperature to which they are exposed, in order to form others, with the vital air in contact with them: such of the principles as cannot unite with the vital air, that is the earth, some saline and some metallic particles, compose the cinder. The new compounds formed, are carbonic acid, or fixed air and water: the proportion of these varies according to the proportion of the carbonic particles, and of the hydrogen that had been contained in the inflammable body." Vol. i. page 163.

‡ "It was said of old that the Creator *weighed* the dust, and *measured* the water when he made the world. The *first* quantity is here *still*; and though man can gather and scatter, move, mix and unmix, yet he can destroy nothing: the putrefaction of one thing is a preparation for the being, and the bloom, and the beauty of another. Something gathers up *all* fragments, and nothing is lost." Robinson. See Add. Notes, No. xxxvii.

§ The indestructibility of matter is beautifully expressed in the following lines by Dr. Darwin:—

"Hence when a monarch or a mushroom dies,
Awhile extinct the organic matter lies;
But, as a few short hours or years revolve,
Alchymic powers the changing mass dissolve;
Emerging matter from the grave returns,
Feels new desires, with new sensations burns;
With youth's first bloom a finer sense acquires,
And LOVES and PLEASURES fan the rising fires."

CHAPTER XIII.

OF ATTRACTION, REPULSION, AND CHYMICAL AFFINITY.

*What is attraction**?

Attraction is an unknown force, which causes bodies to approach each other†.

Which are the most obvious instances of attraction?

The gravitation of bodies to the earth; that of the planets towards each other‡; and the attractions of electricity and magnetism.

Are you acquainted with other instances of attraction?

Yes: attraction subsists between the *particles* § of bodies; and

* In compiling this chapter, I have availed myself not only of Dr. Thomson's and other systems of chymistry, but also of Dr. Duncan's Introd. to the New Edinburgh Pharmacopœia.

† Attraction has, by some philosophers, been attributed to an inherent property of matter, and by others to the influence of some foreign agent. The former is perhaps the most probable supposition.

‡ Sir Isaac Newton demonstrated, that the planetary attraction is the same principle as gravitation. To this principle we are indebted for the periodical flux and reflux of the tides, and for other important operations of nature.

> For this the moon thro' heav'n's blue concave glides,
> And into motion charms th' expanding tides;
> While earth impetuous round her axle rolls,
> Exalts her wat'ry zone, and sinks the poles.
>
> FALCONER.

§ If common flowers of sulphur and potash be mixed and thrown into water, the sulphur will separate; but if they be previously melted together, the union will then be perfect; for the moleculæ will be intimately combined, and the co[illegible] if treated with water will be completely soluble. The design [illegible]eriment is to show that chymical affinity has no sensible action [illegible]ementary moleculæ of bodies.

it is this kind of attraction which comes under the more immediate cognisance of chymists*.

How is this kind of attraction defined in chymical language?

Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion*†, or the attraction of *aggregation*; but when between the particles of different substances, it is called the attraction of *composition*, or chymical *affinity*‡.

Can you explain with more precision what is meant by attraction of aggregation§?

* All the operations of chymistry are founded on the force of attraction which nature has established between the particles of bodies, and by which force all bodies cohere. The art of chymistry employs different means to destroy this attraction of cohesion, and to form fresh substances by the means of new attractions. Take silex as an instance:—In this earth the attraction of cohesion is so strong that the most powerful acids, (one excepted) have no action upon it. But if the strength of this cohesion be broken by fusing it with an alkali, it then becomes obedient to some of the other acids, and may be held in solution by them.

† It is from the attraction of cohesion that water in drops is always spherical, and that small particles of quicksilver are constantly of a globular figure. In consequence of the same species of attraction, particles of water and other liquids ascend in capillary tubes. If a small plate of glass be laid upon a globule of mercury, the glonule, notwithstanding the pressure, continues to preserve its round figure. If the plate be gradually charged with weights one after another, the mercury becomes thinner and thinner; but as soon as the weights are removed, it recovers its globular figure again, and pushes up the glass before it.

‡ A piece of loaf sugar broken into fine powder, or water in the state of vapour by heat, is said to have its attraction of aggregation broken; but the smallest atom of the powder is still sugar, as is the most trifling portion of the vapour to be considered as a part of the water. In order to exemplify the latter kind of attraction, a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common culinary salt. An instance this, of two heterogeneous bodies producing by their action on each other a distinct substance, possessing the properties of *neither* of the bodies which compose it. See Add. Notes, No. vii. Also several instances of chymical affinity in the chapter of Amusing Experiments.

If several salts be dissolved in the same water, when they crystallize, each particle will find its own kind by a sort of innate polarity. To prove this, dissolve half a pound of sulphate of copper and an equal weight of crystals of nitrate of potash in separate quantities of boiling water; pour them together while hot into a flat pan, and when the water has evaporated a little the salts will shoot:—the sulphate of copper altogether in blue, the nitre in white crystals, the same as before they were dissolved. Walker.

§ There are different kinds of aggregation, viz solid, soft, liquid, and gaseous. A stone is an instance of the first, jelly of the second, water of the third, and atmospheric air of the last

If we carefully notice two small particles of mercury while gently moved along a smooth surface towards each other, a mutual attraction of one to the other will be very evident at the moment of their union into one globule. Two small pieces of cork floating in a bason of water, if not nearer to than to each other, will visibly approach, and at last come into conti

The particles of all bodies are possessed of the inherent property of attracting each other, which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

What do you understand by attraction of composition, or chymical affinity?

The particles of every simple substance have not only an attraction among themselves, forming the aggregation of that body or substance; but they have also another attraction to such other substances with which they have an affinity; and, when presented, unite to them, and form a new compound*.

What are the laws of chymical affinity†?

Chymical affinity can only exist between the particles of opposite and distinct substances; and this species of attraction is exerted with different force, according to the nature of such substances, and frequently in proportion to the mass. Most bodies combine only in certain proportions‡:—the new combinations acquire new properties§, and are incapable of separation by mechanical means.

The force of the attraction of aggregation in solid bodies may be measured by the weight necessary to overcome it. Thus if a rod of metal, glass, wood, &c. be suspended in a perpendicular direction, and weights be attached to its lower extremity till the rod is broken by them, the weight attached to the rod just before it broke is the measure of the cohesive force of the rod.

* This power was by Bergman called *elective* attraction, supposing matter to be endued with the ability to choose with which substances it will unite, and which not. *Chymical affinity* is a more definite term, and is now in general use.

Those substances which are capable of uniting, are said to have a chymical affinity for each other; those which do not form a chymical union, are said to have no affinity. The *varied* influence of this property of matter may be attributed by the atheist to *chance*; but the man of sober reflection, who allows the evidence of a mass of facts to have its natural influence upon his mind, will be persuaded that chymical affinity can neither be ascribed to accident, nor to a necessity in the nature of things; for perceiving that the works of nature and art are all governed by this astonishing principle, he will attribute the whole to the contrivance, to the wisdom, and to the goodness of an intelligent Agent, who has varied its operation in a thousand ways, to suit the designs of his beneficence, and to promote different and distinct purposes of utility and happiness.

† There are several laws of chymical affinity; but these may be studied with more effect when the first elements of the science are understood. They are well explained by Thomson, Fourcroy, and others.

‡ Thus oxygen and hydrogen combine only in one proportion, and the result is water. Nitrogen and hydrogen combine only in one proportion, and ammonia is the result.

§ If we melt together equal quantities of tin and iron, two malleable and ductile [illegible] the compound produced will have totally lost the properties which [illegible]ent parts possessed before their union; for the alloy formed will [illegible] rittle metal. If liquid ammonia and muriatic acid, both

How are the different kinds of chymical affinity distinguished?

Chymical affinity is of three kinds, viz. simple affinity, compound affinity, and disposing affinity.

What is simple affinity?

When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of simple affinity*.

What is compound affinity?

The action of two compound substances whereby they mutually decompose each other, and produce two or more new compounds†.

fluids of a strong odour, be mixed in proper proportions, a fluid will be produced entirely devoid of smell, viz. muriate of ammonia.

If nitrate of ammonia and sulphate of soda, both in crystals, be rubbed together in a stone mortar in equal proportion, the mixture will be converted to a fluid.

* The following experiments will serve to exemplify some cases of simple affinity:—Take a portion of acetate of soda; pour muriatic acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater affinity for muriatic acid than it has for the acetic. If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda. If to the nitrate of soda, sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the alkali, forming a true sulphate of soda. These changes all take place in consequence of chymical affinity. Owing to this affinity acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid, have each of them a stronger affinity for soda, and their respective affinities are in the order in which they have been named.

† If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger affinity for ammonia than nitric acid has. But if a solution of nitrate of potash be poured in, we obtain by evaporation two new bodies, *sulphate of potash* and *nitrate of ammonia*. In this case, the sulphuric acid of the sulphate of ammonia attracts the potash of the nitrate of potash, at the same time that the ammonia attracts the nitric acid; and to the agency of these united affinities the double decomposition must be attributed. The manner in which these combinations take place was thus explained by Dr. Black:— Let the affinity between potash and sulphuric acid be = 62; that between nitric acid and ammonia = 38; that between nitric acid and potash = 50; and that between the sulphuric acid and ammonia = 46. Now, let us suppose that all these forces are placed so as to draw the ends of two cylinders crossing one another, and fixed in the middle in this manner:

What do you mean by disposing affinity?

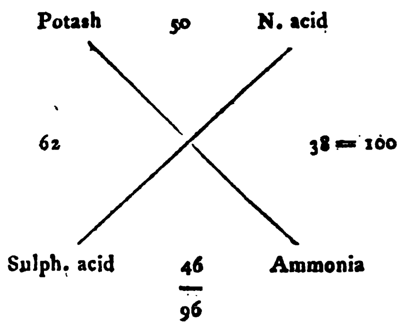
When bodies, which apparently have no tendency to unite of themselves, combine in consequence of the addition of another substance which has a strong affinity for the compound, the union is said to be produced by means of *disposing* affinity.

What other terms are employed on the subject of chymical affinities?

There are what are called *quiescent* attractions, and *divellent* attractions.

What do you mean by quiescent attractions?

When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated the *quiescent* affinities*.



It is evident, that as 62 and 38 = 100 are greater than 50 + 46 = 96, they would overcome the other forces, and shut the cylinders.

In like manner acetate of alumine, which is used by the dyers and calico-printers, cannot be formed by the direct mixture of its component parts; for acetic acid exerts no action upon alumine, however its parts may be divided by mechanical means. But if I mix sulphate of alumine with acetate of lead, a mutual decomposition will take place, and the article I require will be produced.

If *concentrated* nitric acid be poured upon iron no union will take place. The component parts of the nitric acid have so great an affinity for each other that the iron has no power to effect a decomposition. But if a few drops of water be added, the union between the oxygen and nitrogen of the nitric acid will be weakened, part of its oxygen will combine with the iron, a violent action will take place, clouds of nitrous gas will be disengaged in abundance, and the iron will soon be entirely dissolved in the acid.

* If a solution of nitrate of silver be poured into solution of muriate of soda, two new substances will be formed, viz. nitrate of soda, and muriate of silver; the latter of which, being insoluble in water, will be precipitated in a solid form. In this experiment the affinity of the nitric acid to the silver, and the muriatic acid to the soda are the *quiescent* affinities; whereas the aff[illegible] f the nitric acid to the soda, and the muriatic acid to the silver are [illegible] *t* affinities.

[illegible] w arrangement of parts in any mixture can take place, unless di[illegible] ion exist.

What is meant by divellent affinities?

Those attractions which tend to destroy the original compound, and to form new arrangements, are called the *divellent* affinities.

What advantage do we derive from the study of chymical affinities?

From all that has hitherto been explained this seems to be beyond doubt the most important part of chymistry; for it is only from a thorough knowledge of the affinities which different substances have for each other, that we shall ever attain a complete analysis of every thing which nature has afforded us.

How should a pupil proceed to acquire what seems so essential to chymistry—a knowledge of these affinities?

He must practise as well as study the various tables of affinities of Bergman, Pearson, and others. The original tables were compiled by Geoffroy, near a century ago.

How are chymical affinities noted in these tables?*

Among the affinities of any substance, there is generally at least one peculiar to that substance which stamps it as one of its generic characters; and it is of the utmost importance to the student to imprint these characteristics upon his mind, in the most early stage of his progress, as often as he happens to meet with them. It is these predominating affinities which are more particularly serviceable in the classification of the chymical properties of different substances, and of the chymical phenomena derived from them. Thus affinity for oxygen distinguishes inflammable substances; and the reciprocal affinity of acids and alkalies constitute acidity and alkalinity. Thus barytes has a peculiar affinity for sulphuric acid, and lime for the oxalic acid, &c.

* The following single example may serve as a specimen of the tables of affinities, and will be sufficient to explain the nature of all others. Let the question be sulphuric acid, and it will be formed thus:—

SULPHURIC ACID.

Barytes.
Strontian.
Potash.
Soda.
Lime.
Magnesia.
Ammonia.
Alumine.
Metallic oxides.
Water.
Alcohol.

The foregoing table is designed to show that barytes has the strongest affinity for sulphuric acid, and alcohol the weakest; actual experiment will

The name of the substance whose affinities are required is always placed at the head of the column, and separated generally by a line; below this the other bodies are placed in the order of their attraction to the first substance: thus in respect to the affinities peculiar to *sulphuric acid*, it appears that barytes, which is the nearest, would separate strontian, potash, or any one of the succeeding substances from sulphuric acid, which prefers barytes to all other bodies whatever.

Are these tables to be depended upon in every case of chymical composition and decomposition?

These tables notwithstanding some exceptions*, are so extremely useful that the study of them cannot be too strongly inculcated; for in most cases they may be safely trusted by the practical chymist.

What is repulsion?

Repulsion is a peculiar property, inherent in the particles of all matter, which gives them a constant tendency to recede from each other†.

confirm it. For if to a compound of sulphuric acid and alcohol water be added, the sulphuric acid will leave the alcohol to unite with the water; if a metallic oxide be then added, the sulphuric acid will quit the water, and unite with the oxide; and if soda be afterwards added, the sulphuric acid will leave the metallic oxide to unite with the soda, and the oxide will be separated in a pulverulent form.

* The affinities of bodies are affected by the proportions in which they are presented to each other, by the cohesion of their parts, by chymical repulsion, &c. Berthollet has shown that substances are capable of decomposing each other reciprocally, if they be added respectively in the proper quantity. Thus sulphuric acid decomposes nitrate of potash altogether, by the assistance of heat. The nitric acid is driven off, and there remains behind sulphate of potash. But if nitric acid be poured into sulphate of potash in sufficient quantity, it takes a part of the base from the sulphuric acid, and nitrate of potash is regenerated. In like manner phosphoric acid decomposes muriate of lead, and muriatic acid decomposes phosphate of lead.

† Sir Isaac Newton found that when a convex lens was put upon a flat glass, it remained at the distance of the 1-137th part of an inch; that a very considerable pressure was required to diminish this distance, and that no force which can be applied will bring them into actual mathematical contact. Other philosophers have shown that the particles of no body whatever are in mathematical contact; that in every case there is a distance between them; consequently that the particles of all bodies *repel* each other. According to Boscovich, the atoms of which all bodies are composed are mere mathematical points, destitute of extension and magnitude, but capable of acting on each other with a force which differs in intensity, and in kind, according to the distance. At sensible distances the force is *attractive*, and diminishes inversely as the square of the distance. At the smallest distances the force is *repulsive*; it increases as the distance diminishes, and at last becomes infinite, or insuperable; so that absolute contact, of course, is impossible. Dr. Thomson, vol. iii. 272. The particles of all gases, and of atmospheric air evidently repel each other. It is to repulsion that they are indebted for their elasticity.

How does this property of matter operate?

It operates at sensible and at insensible distances.

What instances are there of the former kind of repulsion?

The only kinds of repulsion that can be exhibited to the senses, are those of electricity*, and magnetism†; but it is *insensible* repulsion with which chymists are more particularly concerned.

What instances have you of this latter kind, or of insensible repulsion?

The only example that we are acquainted with is the repulsion of the particles of caloric‡ amongst themselves; which repulsion would constantly tend to infinite separation, were it not for a chymical union, which, by an irrevocable law of nature, they form with the first surrounding body. For by that law it seems the particles of caloric cannot exist in an isolated state.

How does this repulsive force operate upon other *bodies?*

It diminishes the cohesion of the integrant particles of all heated bodies, in consequence of the particles of caloric repelling each other; so that chymical unions, as well as chymical decompositions, are wonderfully facilitated by this species of repulsion§.

* If two cork balls be suspended from a body with silk threads so as to touch each other, and we charge that body with electricity, the cork balls will separate immediately. The balls of course *repel* each other.

† When we present the north pole of a magnet A to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B recedes as the other approaches; and by following it with A at a proper distance, it may be made to turn round on its pivot with considerable velocity. There is then a *repulsion* between the two magnets—a repulsion which increases with the power of the magnets; and this power has been made so great, by a proper combination of magnets, that all the force of a strong man is insufficient to make the two north poles touch each other.

‡ It is now generally imagined that what is called insensible repulsion is owing to the presence of caloric. It is well known that the elasticity of air and all other gaseous bodies is increased by heat; that is, that the repulsion between the particles of air, the distance remaining the same, increases with the temperature, so that at last it becomes so great as to overcome every obstacle which can be opposed to it. This subject is fully treated by Dr. Thomson, to whom I refer the reader.

§ It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must tend to facilitate their chymical union with the particles of other bodies. One reason why some bodies require a high temperature to cause them to combine, is, that at a low temperature the attraction of cohesion is in them superior to that of affinity; accordingly it becomes necessary to weaken that attraction by caloric, till it becomes inferior to that of affinity. In like manner bodies combine more easily when held in solution by water, or when they have previously been reduced to a fine powder, as these operations diminish the cohesion which exists among the primitive or integrant particles. Sulphuric acid has no action upon a lump of fluate of lime; but if that earthy salt be reduced to powder, a violent action will ensue on the addition of the sulphuric acid, and the fluate of lime will be decomposed.

Will you endeavour to explain this action of caloric with more precision?

As chymical affinity takes place only between the ultimate molecules of bodies, while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever caloric has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies*.

Is the addition of caloric always necessary to promote chymical affinity?

In order for the attraction of composition to take place between two bodies, it is generally necessary either that one of the substances should be in a state of fluidity, or that heat should be applied; so that caloric acts an important part either sensibly or insensibly in all cases of chymical affinity.

Does chymical affinity operate in consequence of the universal law of attraction?

We have reason to believe that every new compound is produced by virtue of the attraction to which all matter is subject, and which is equally operative on the most minute atom, as on a planetary system†.

How do you imagine that the same force which operates upon the

* The formation of the red oxide of mercury will exemplify the above chymical axiom. If mercury be submitted to a heat little superior to that of boiling water, no new combination will be formed, but the metal will remain unaltered. If the heat be increased to 600°, or thereabouts, the attraction of cohesion of the mercury will be broken; its particles will unite with the oxygen of the surrounding atmosphere; and a new substance, *red oxide of mercury*, will be produced. If this new substance be again submitted to the operation of caloric, and the heat be raised to 1000°, the combination will again be broken, and new affinities will take place. The affinity of oxygen for caloric will now be greater than that of oxygen for mercury; the oxygen will quit the mercury, unite with the caloric, and be expelled as oxygen gas: thus the mercury will consequently once more appear in its metallic state.

Red lead is formed by long exposure of metallic lead to atmospheric air in a high temperature; but by a great increase of temperature, it is made to give out its oxygen in sufficient abundance to be collected in appropriate receivers in the form of oxygen gas, and the metal becomes revived.

† The attraction of the particles of bodies for each other is exemplified by small quantities of water, or other fluids, which, when dropped upon a flat surface, form themselves into spherical masses.

That very law which moulds a tear,
And bids it trickle from its source,
That law preserves the earth a sphere,
And guides the planets in their course.

ROGERS.

ultimate particles of bodies, so as to produce composition and decomposition, can be sufficient to preserve the planets in their orbits?*

We can neither comprehend the one nor the other; nor can we see why the Almighty might not as easily bestow upon one species of matter the power of acting upon another when at a distance†, as the power of being acted upon and changed by matter when in actual contact‡.

Is the consideration of this universal property of matter calculated to produce any peculiar reflections?

The contemplation of this subject has a natural tendency to promote the most profound feelings of awe and admiration; for the understanding of the highest intelligencies sinks into nothing when compared with the energy of that Omnipotent Being, who had wisdom to contrive, and ability to endue the matter which he had formed, with the astonishing Power of operating upon its fellow matter either in contact, or when separated by the infinity

* A passage of Dr. Watson's will perhaps furnish as good a reply to this question as can be given. "We feel the interference of the Deity every where, but we cannot apprehend the *nature* of his agency any where. A blade of grass cannot spring up, a drop of rain cannot fall, a ray of light cannot be emitted from the sun, nor a particle of salt be united, with a never failing symmetry to its fellow, without him; every secondary cause we discover, is but a new proof of the necessity we are under of ultimately recurring to him as the one primary cause of every thing."

† Dr. Herschel has shown, that not only the planets in our system are preserved in their orbits by mutual attraction, but that in the sideral systems the double stars are so situated with respect to each other, that *they* must be subjected to mutual gravitation, and that they can only preserve their relative distances by a periodical revolution round a common centre. What he calls the *insulated* stars he imagines to be nearly out of the reach of mutual gravitation. He considers our sun and all the brightest stars to be of this class. They are of such immense distances, that he calculates that Sirius (the nearest of the fixt stars to us) and the Sun, if left alone would be 33 millions of years in falling together. The same philosopher has said, that though light travels at the astonishing velocity of 200,000 miles in a second, some of the nebulæ are so far from us that the rays of light must have been nearly two millions of years in passing from them to our system. According to a writer in the thirty second volume of the Monthly Review, N. S. 523, astronomers are now acquainted with no less than 2120 of these nebulous stars. Doubtless they are so many distinct worlds, appropriated by the Author of nature for the reception of intelligent beings, and for the abodes of rectitude and felicity.

Lightnings and storms His mighty word obey,
And planets roll where HE has mark'd their way.

‡ Thomson's Chymistry.

of space. Well might a writer of antiquity assert, that God saw every thing that he had made, and behold it was very good*.

* Having now completed my original design of furnishing the YOUNG with an elementary treatise on chymistry, it may be necessary to apologize to some readers for the introduction of those moral reflections which so frequently occur. This cannot be done better than in the language of a late popular writer :—" Every man," says he, " has a particular train of thought into which his mind falls, when at leisure from the impressions and ideas that occasionally excite it; and if one train of thinking be more desirable than another, it is surely that which regards the phenomena of nature with a constant reference to a supreme intelligent Author." Paley.

ADDITIONAL NOTES.

I. *Of Specific Gravity.*

THE common method of taking the specific gravity of the metals, or of any solid body, is by comparing the difference which there is in their weight when weighed in air and in water; that is, to divide the *absolute* weight by the *loss*, and the quotient is the specific gravity. Thus, if a mineral which weighs three ounces in air, weighs only two ounces when weighed in water, the specific gravity of such mineral is 3; that is, if water, as it generally is, be called 1.000, the substance now examined is 3.000; or, to make it plain to the young student, if a pint of water weigh *one* pound, the same *bulk* of the mineral will weigh three pounds. See page 38.

A more ready way to determine the specific gravity of solids is to fill a phial with water, and note the weight of the whole accurately in grains. Then weigh 100 grains of the mineral or other substance to be examined, and drop it gradually into the phial of water. The difference of weight of the bottle with its contents now, and when it was filled with water only, will give the specific gravity of the matter under examination. For example, if the bottle weighs 50 grains more than it did when it was filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that it is twice the specific gravity of water. This method is said to have been discovered by Archimedes. See Note, page 35.

The specific gravity of fluids is generally determined by an aräometer, which is a graduated glass tube with a bulb, so contrived that it may swim in the fluid in a perpendicular position. The specific gravity is shown by the degree to which this instrument sinks in the fluid to be examined, and this will consequently always be lower in proportion as the liquid is lighter.

The specific gravity of ardent spirits is generally ascertained by means of an hydrometer, of which various kinds are sold by the mathematical instrument makers.

The following method, which was contrived by Dr. Lewis, the celebrated author of the Commercium Philosophico-Technicum, and which was communicated to me by the amiable Samuel Moore, esq. late secretary to the Society for the promotion of arts, manufactures, and commerce, I prefer to every other.

In this method the specific gravity of a liquor is estimated from the excess of the weight of a certain measure of it above that of an equal measure of distilled water. A set of weights is made for this purpose, called *carats*, or *cadukes*, in the following manner:

A convenient bottle being procured, the tare of the bottle is first taken; it is then completely filled with distilled water; the weight of the water is accurately divided into two equal parts, and a weight made equal to one of these parts is marked 64; by continuing the division, are obtained the weights 32, 16, 8, 4, 2, 1 carats; so that a carat is the 128th part of the weight of the water. Another weight is then made which counterpoises the bottle when filled with water; and so many carats as the bottle filled with an alkaline lye, or any other liquor, weighs more than this waterpoise, so many carats strong is the liquor said to be.

A table of these carats, with their corresponding degrees of specific gravity, which I drew up for my own use, will be found with the tables at the end of this volume.

II. *Of the Barometer.*

The height at which the mercury stands in the barometer varies at times in consequence of the variation in the *weight* of the atmosphere. From a knowledge of this fact, this instrument has been made use of to measure the height of mountains, and by aëronauts to ascertain the height they ascend in the air. It is found that the barometer varies about an inch for every 600 feet. See pages 47 and 49; also sir George Shuckburgh's paper, in the Philosophical Transactions, vol. lxxvii.

III. *Of Ebullition.*

Under an exhausted receiver, water will boil at the heat of 92° of Fahrenheit's thermometer; whereas under the usual pressure of the atmosphere it does not boil till it is heated to 212°; though, as the atmosphere varies in density, it occasions some little variation in this respect; for sir George Shuckburgh found by experiment, that when the barometer was at 26 inches, water boiled at less than 205 degrees, but when it was at 31 inches it required to be heated to near 214° before it would boil.

Under the common pressure of the atmosphere

Ether boils at	98°
Alcohol	176
Water	212
Nitric acid	248
Sulphuric acid	546
Phosphorus	554
Mercury and Linseed oil	600

Dr. Black made experiments upon several liquids in vacuo, and found that in general they all boiled with about 140 degrees of heat less than when bearing the weight of the atmosphere. Vitriolic ether (if the pressure of the atmosphere be removed) will boil when 52 degrees below the cold sufficient for freezing water. See pages 48 and 79.

IV. *Of the Atmosphere.*

Besides the advantages which have been enumerated, the atmosphere is of great use in preventing the heat, which the earth acquires from the sun, from being soon dissipated; the air being a bad conductor of heat. It is owing to this property of atmospheric air that our clothes preserve the heat of the

body; for it is not the clothes, but the air which is folded within them that produces the effect. See page 49; also Rumford's Essays.

V. *Of Chymical Decomposition.*

The changes which matter perpetually undergoes by the decomposition of all organized beings, probably gave rise to the ancient doctrine of transmigration. See pages 52 and 239.

The sacred seer with scientific truth
In Grecian temples taught the attentive youth
With ceaseless change how restless atoms pass
From life to life, a transmigrating mass;
Whence drew the enlighten'd sage the moral plan,
That man should ever be the friend of man;
Should eye with tenderness all living forms,
His brother emmets, and his sister worms. DARWIN.

VI. *Of Oxygen Gas.*

Details of several surprising cures by means of oxygen gas may be seen in the different volumes of Mr. Tilloch's Philosophical Magazine*. By the new invented gasometers, and the apparatus sold with them, any kind of factitious air may be accurately measured, and mixed with any portion of atmospheric air that the physician may prescribe. See page 54. The addition of more oxygen gas to atmospheric air has been very efficacious in asthmas, vertigos, cutaneous eruptions, &c. but peculiarly so in those female complaints which arise from want of sufficient tone and vigour in the system.

Thus the afflicted, feeble, languid maid,
Whose health, whose spirits, and whose roses droop,
Looks to pneumatic chymistry for aid,
And views the neat gasometer† with hope.

Anxious she marks the mixture of the airs,
And joys to hear them bubble and expand‡;
While fell Hysteric every sinew tears,
And overwhelms her with his leaden hand.

Trembling she grasps the cold metallic tube,
In fear mysterious, and with caution drinks;
While every pulse acquires a kinder throb,
And still increases as the envelope § sinks.

The heaving lungs inhale the vital gas,
The blood absorbs it as it ebbs and flows;
It gives fresh colour to the fluid mass,
And the whole frame with pristine vigour glows.

* See also an interesting "Essay on the Medicinal Properties of Factitious Airs," by Tiberius Cavallo, esq. 8vo. Dilly, 1798.

† The gasometer is a machine from whence the factitious airs are inhaled.

‡ When the oxygen gas is prepared, it is thrown up through water, into the gasometer in bubbles where it expands and mixes with the proper proportion of atmospheric air.

§ The envelope is the covering of the gasometer, which preserves the air from escaping; it is hung upon pulleys, and sinks lower and lower in the water, as the gas is inhaled from underneath it.

Returning health adorns the roseate cheek,
And decks the features with its every charm;
While new desires, new energies bespeak,
And beauty's self resumes her native form.

With emulation now her bosom burns;
The grateful female cultivates her mind,
And feels the sweetest pleasure while she learns
The science* sent by Heaven to bless mankind.

S. P.

VII. *Of the Production of Oxygen Gas.*

Oxygen gas may be procured in any quantity from the black oxide of manganese, which is a cheap article, worth only a few shillings per cwt. It is only necessary to pulverize the manganese, and expose it in an iron retort to a proper degree of heat. The gas, which will rise in great plenty from the retort, may be received in bladders, or any appropriate vessels. Dr. Priestley, who discovered this air, called it dephlogisticated air. According to Mr. Parkinson, one pound of manganese will furnish ten gallons of this gas. Berthollet says that oxygen gas may be procured with more ease, and in greater purity, from the oxygenized muriate of potash than from any other substance; but as this is a dear article, manganese will be chosen for all common purposes. See page 55.

VIII. *Of the Effect of Oxygen upon the Blood.*

To prove that oxygen gas is really imbibed by the blood in the lungs, Dr. Goodwin opened the chest of a living dog, and exposed the lungs and heart to view. It was a striking spectacle to observe the *black* blood, in its return from the lungs, and in its passage to the heart, change to a bright *vermilion* colour. As the dog became exhausted, it was found necessary to inflate the lungs by artificial means. When this was omitted, the blood received by the heart was black, and in a little time its action ceased. But when the lungs were again made to collapse and distend, by the inflation of common air, the blood in the pulmonary vessels regained its former crimson colour, and the action of the heart and arteries was excited anew. See p. 57.

IX. *Of the Circulation of the Blood.*

According to Dr. Thomson, one principal use of the blood is to furnish fibrina to supply the waste of the muscles; for as neither the chyle nor the lymph contains fibrina when they flow into the blood, there must be a continual decomposition of chyle and lymph in the blood-vessels, in order to form this substance. We know that carbon and hydrogen are thrown out by the act of respiration; he therefore concludes that one use of the air absorbed is to abstract a quantity of carbon and hydrogen from the chyle, by compound affinity, in such proportions that the remainder becomes fibrina†. For the information of young readers, the following account of the apparatus for elaborating the blood is copied from Paley's Natural Theology:

"There is provided in the central part of the body a hollow muscle, invested with spiral tubes, running in both directions. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain: by the relaxation of the same fibres, the cavities are in their turn dilated;

* Chymical knowledge in general.
† System of Chymistry.

and, of course, prepared to admit every fluid which may be poured into them. Into these cavities are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back. This is a general account of the apparatus: and the simplest idea of its action is, that, by each contraction, a portion of blood is forced as by a syringe into the arteries; and, at each dilatation, an equal portion is received from the veins. This produces at each pulse, a motion and change in the mass of blood, to the amount of what the cavity contains, which in a full grown human heart is about an ounce, or two table-spoons full. Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour; from which it follows, that there passes through the heart every hour four thousand ounces, or 350lbs. of blood. Now the whole mass of blood is about 25 pounds; so that a quantity of blood equal to the whole blood within the body passes through the heart fourteen times in one hour; which is about once every four minutes. Only consider what this is in very large animals. The *aorta* of a whale is larger in the bore than the main pipe of the water-works at London bridge; and the water roaring in its passage through that pipe is inferior in impetus and velocity to the blood gushing from the whale's heart." According to Dr. Hunter, ten or fifteen gallons of blood are thrown out of the heart of a whale at a stroke, with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder. See Dr. Hunter's account of the dissection of a whale, in the Philosophical Transactions.

"It was necessary that the blood should be successively brought in contact or proximity with the air; therefore, as soon as the blood is received by the heart from the veins of the body, and before that it is sent out again into its arteries, it is carried by the force of the contraction of the heart, and by means of a supplementary artery, to the lungs; from which, after it has undergone the proper change, it is brought back by a large vein once more to the heart, in order, when thus prepared to be from thence distributed anew into the system. See page 57.

"An anatomist, who understood the structure of the heart, might say beforehand that it would play: but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement; or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time without disorder, and without weariness."

X. *Of the Renovation of the Atmosphere.*

It has been imagined that the atmosphere is occasionally renovated from other sources. Dr. Darwin, in his dissertation on the winds, concludes that immense masses of air are set at liberty from their combinations with solid bodies, within the polar circle, or in some region to the north of us; and that they thus perpetually increase the quantity of the atmosphere; and that this is again at certain times re-absorbed, or enters into new combinations at the line or tropical regions. By which wonderful contrivance the atmosphere is perpetually renewed, and rendered fit for the support of animal and vegetable life. Botanic Garden.

The following idea is merely hypothetical, but it deserves perhaps some notice.—"The *moisture* contained or dissolved in the ascending heated air at the line, must exist in great *tenuity*, and by being exposed to the great light of the sun in that climate, the water may be decomposed, and the new airs spread on the atmosphere from the line to the poles." Ibid.

On liquid air He bade the columns rise,
That prop the starry concave of the skies;
Diffus'd the blue expanse from pole to pole,
And spread circumfluent ether round the whole.

BLACKLOCK.

The action of the sea also has probably considerable influence in purifying the atmosphere. See page 60.

XI. *Examples of Affinity.*

Take a little common magnesia, and pour by degrees diluted nitrous acid upon it till the whole of the earth be dissolved. This is an instance of simple chymical affinity. But if a solution of potash be poured upon the former mixture, the potash having a greater affinity for the acid will take it from the magnesia, and the magnesia will again be precipitated.

To a solution of soap add a little weak sulphuric acid. The acid having a stronger affinity for the alkali of the soap than the alkali has for the tallow, the acid will unite with the alkali, and the separated tallow will be seen to float upon the surface of the liquor.

Dissolve a few ounces of sulphate of iron in water, by adding the salt by degrees till the liquor becomes turbid; then if a skain of cotton thread be dipped in the solution and shaken a little in it, the thread will take up the whole of the oxide of iron, and render the liquor transparent. This effect is produced in consequence of the great affinity which cotton has for the oxides of iron.

If mercury be put into a *glass* bottle, the surface will appear convex, owing to the small affinity which mercury has with glass; but if it be put into a *metallic* vessel, the surface of the mercury will appear concave like that of other fluids, because of its tendency to combine with the sides of the vessel. This may be adduced as a striking proof of metallic elective attraction.

"The phenomena of dyeing may be referred entirely to chymical principles. The colouring particles possess chymical properties that distinguish them from all other substances; they have attractions peculiar to themselves, by means of which they unite with acids, alkalies, metallic oxides, and earths. The difference in the attractions of the colouring particles for wool, silk, and cotton, is sometimes so great that they will not unite with one of these substances, while they combine very readily with another; thus *cotton* receives no colour in a bath which dyes *wool* scarlet." Berthollet, vol. i. page 22. Several curious and instructive instances of the effects of chymical affinity in the art of dyeing may be seen in that work, vol. i. page 29, and following pages.

Chymical affiinity may be pleasingly illustrated by the composition and decomposition of writing-ink. Take a little tincture of galls, and a little of the solution of green copperas, both colourless liquors, and if poured together the mixture becomes black; from the affinity which gallic acid has for the oxide of iron in the copperas. Then pour in a little weak aqua-fortis, and the liquor will become immediately transparent; this arises from the metal leaving the first acid to unite with the last, to which it has a greater affinity. But if a solution of potash be now added, the nitrous acid will quit the iron, and unite with the alkali: thus the iron being once more disengaged will again be caught by the gallic acid in the infusion, and once more produce a black liquor. See page 74.

XII. *Atmospheric Pressure.*

The rise of water in a pump was formerly attributed to the horror that nature had of a vacuum. This absurd notion was refuted about the middle of the seventeenth century, by the following occurrence:

The Duke of Florence, having occasion to raise water to the height of 50 or 60 feet, ordered a common pump to be made for that purpose; but when it was completed the workmen were astonished to find that it would not work.

The matter was referred to the celebrated Galileo, but he was unable to account for it in any way. All they were able to determine was, that water would not rise in a common pump more than from 32 to 35 feet. The fact remained inexplicable till philosophers caught the idea of atmospheric pressure; since when, the suspension of mercury in the barometer, and water in a pump, have been well understood. See page 47.

XIII. *Of the Formation of Water.*

In 1798, Mr. Seguin made a grand experiment for the composition of water. He expended no less than 25,582 cubic inches (or nearly two hogsheads) of inflammable air, and 12,457 of vital air. The first weighed 1039 grains, and the second 6210, amounting to 7249 grains, and the water obtained amounted to 7245 grains, or about three fourths of a wine pint. The loss was only four grains. Another experiment was afterwards made by Le Fevre, in which nearly two pounds and a quarter of water were produced*. See page 81.

XIV. *Of the Colour of the Blood.*

The colour that the blood acquires by the absorption of vital air may be accounted for on chymical principles. Blood contains much iron; and it seems that this iron is oxidized by the oxygen gas which it receives by the lungs, and that the colouring matter of the blood is the red oxide of iron. If the coagulum of the blood be washed, it may be rendered colourless; but then it will be found to contain no iron.

XV. *Of the Decomposition of Water.*

"When a great number of electric sparks are conveyed through a small tube, filled with water, by means of a conductor with a metallic knob, the water is decomposed, and separated into oxygen and hydrogen gas; and when this decomposition is so far advanced that the two extremities become immersed in the mixture of these two gases, so that the spark explodes in them, the gases take fire, and again form water†." See page 81.

XVI. *Of Combustion.*

It may be remarked that animal and vegetable substances are converted into water and carbonic acid during combustion, by the union of their hydrogen and carbon with the oxygen of the atmosphere; and, in process of time, that the same water and carbonic acid are absorbed by vegetables, and decomposed by them in order to set the oxygen at liberty to produce fresh combustions, while the vegetating organs appropriate the hydrogen and carbon to themselves, to promote their growth and nourishment. Thus a regular circle of compositions and decompositions is perpetually going on, and all organized beings are made to surrender in due time, to the general mass, those elementary substances which nature kindly lent them for the preservation of their existence. See page 83.

Is not this admirable simplicity of nature a conclusive proof of the infinite wisdom of the Deity, and that the greatest possible sum of beauty and of happiness was his ultimate object?

* Dr. Black. † Fourcroy.

The whole and every part proclaims
His infinite good-will;
It shines in stars, and flows in streams,
And bursts from every hill.

We view it o'er the spreading plain,
And heav'ns which spread more wide;
It drops in gentle show'rs of rain,
And rolls in ev'ry tide.

BROWNE.

XVII. *Of the Effects of Intense Cold.*

In Iceland and Germany the thermometer frequently falls to zero, which is 32 degrees below the freezing point. When stones or metals which have been exposed to such such degrees of cold, are touched by the tongue, or the softer parts of the human body, they absorb the heat from those parts with such rapidity that the flesh becomes instantly frozen and mortified, and the principle of life in them is extinguished. Some French academicians who made a journey to the north end of the Baltic, and wintered under the polar circle, found it necessary to use all possible precautions to secure themselves from the dreadful cold which prevailed. They prevented as much as possible the entrance of the external air into their apartments; and if at any time they had occasion to open a window or a door, the humidity of their breath, confined in the air of the house, was condensed and frozen into a shower of snow; their lungs, when they ventured to breathe the cold air, felt as if they were torn asunder; and they often heard the rending of the timber around them by the expansive power of the frost on the fluid in its pores. In this terrible cold the thermometer fell to 33° *below* zero*. The most intense cold ever known in the neighbourhood of London was on December 25, 1796, when the thermometer indicated 2° below zero. See page 86.

XVIII. *Of the Recession of the Ocean.*

At the summit of Mount Perdu, in the Pyrenees, which is nine thousand feet above the level of the sea, a prodigious number of marine productions are found, which seem to indicate that there has been either a great recession of the ocean, or a vast elevation of the mountainous parts of the earth. The former is perhaps the most probable supposition. What then has become of this immense body of water? Some have supposed that it has risen into the atmosphere, and remains suspended there; some, that it has found a place in the heart of the globe; and there are others who even imagine that it has passed off to other planets. But since it is known that water is a compound decomposable substance, other solutions of this difficult question might be given. Water enters into the composition of most substances; and if it unite to some without losing its nature, it cannot combine with others unless it be decomposed, and cease to be water. It is thus that it abandons its oxygen to metals, and its hydrogen to plants. These two principles once separated, cannot unite again to form water, but by a concurrence of circumstances which does not often take place. M. Poiret, who has written upon this subject, in the sixtieth volume of the Journ. de Phys. seems to be of opinion, that when the earth was nearly covered with water, a considerable portion of this fluid would necessarily be consumed by marine animals, which would of course be more numerous as the mass of waters was greater. This supposition is strengthened by our knowledge of one circumstance, that hydrogen is the base of animal fat, and that in no animal is fat so abundant,

* Dr. Black's Lectures.

as in various species of fish, especially in the cetaceous tribe, of whose substance it often constitutes the principle part. Besides, there existed vast numbers of shell fish, and of polypi, which latter employ themselves in constructing calcareous rocks, that are uniformly composed of the pulverized remains of their shells and their tubes joined together; which insensibly raising themselves from the sea, have reached the surface of the water. These rocks at first were mere barren islands, but soon afterwards became covered with an abundant vegetation. This great work was thus effected at the expense of the waters, which diminished more rapidly as organized beings became more numerous. He goes on to state, that a vast consumption of water has been occasioned by volcanos, and by the formation of stony bodies; some of which, particularly the calcareous, frequently contain one fourth of their mass of water. The last cause of the consumption of the water which he mentions, is the vegetation of plants. By this process water is plentifully and perpetually decomposed, and more and more so, in proportion as the surface of the earth increased. Hales found that a plant which weighed three pounds, acquired an augmentation of two pounds, after remaining for some time with its roots in water. If to this fact we add the idea of a vegetation existing for thousands of ages, and of those immense forests which once covered the countries now cultivated; and lastly, the extensive depths of peat, and the thick beds of coal, that are so many vegetable remains, what an idea must we have of the enormous quantity of water necessary for the formation of all these substances, and for the support of such an abundant vegetation for such a period of time! See page 88.

A late discovery made by Mr. Harrop, and which I have noticed in page 88 of this work, adds another source to those already enumerated by M. Poiret, to prove the diminution of water. This discovery announces a power in nitrogen gas to absorb oxygen from water, till the mixture of nitrogen and oxygen arrives at that proportion which constitutes atmospheric air.

> Water restrain'd gives birth,
> To grass and plants, and thickens into earth;
> Diffus'd it rises in a higher sphere,
> Dilates its drops, and softens into air;
> Those finer parts of air again aspire,
> Move into warmth, and brighten into fire;
> That fire once more, by denser air o'ercome,
> And downward forc'd, in earth's capacious womb
> Alters its particles, is fire no more,
> But lies metallic dust, or pond'rous ore.
>
> PRIOR.

XIX. *Of Hard Water.*

Lime is found, variously combined, in the waters of most springs and rivers. Waters which contain a large portion of selenite, or sulphate of lime, are very unwholesome; though they may in a great measure be purified by boiling. It may however be acceptable to some readers to be informed that these waters may be entirely freed from the calcareous impurities, by a very small addition of potash. This will attract the acid, and the lime is then precipitated in the state of chalk: hence the use of potash added to water for boiling vegetables, and for purposes in which hard water would be prejudicial. See page 101.

XX. *Of Lime and Water Cement.*

Dr. Watson has remarked, that "in countries where they have no common materials for making lime, it would be worth while for the farmer to

examine the earth which may be met with on the surface of the ground, or at a little distance below it; for that calcareous substances are not always united into hard compact masses, but are sometimes found in the form of loose earth, and that of different colours."

While writing on lime, some persons may be glad to be informed how a cement may be made with common lime, that will harden under water. What is called *poor* lime has this peculiar property; but as this species of limestone rarely occurs, it is an expensive article. The following is a good substitute, and may be used for water-cisterns, aqueducts, &c.—Mix four parts of gray clay, six of the black oxide of manganese, and ninety of good limestone reduced to fine powder, then calcine the whole to expel the carbonic acid. When this mixture has been well calcined and cooled, it is to be worked into the consistence of a soft paste with sixty parts of washed sand. If a lump of this cement be thrown into water it will harden immediately. Such mortar however may be procured at a still less expense, by mixing with common quick-lime, a certain quantity of what are called the *white* iron ores, especially such as are poor in iron. These ores are chiefly composed of manganese and carbonate of lime, or chalk. Lime and sand only, whatever may be the proportion of the mixture, will certainly become *soft* under water.

XXI. *Of Light.*

This work being intended to instruct very *young* persons in the first principles of natural and chymical philosophy, I purposely omit entering into a general investigation of the nature of *light*. It is a subject but imperfectly understood, and what is known is in general too abstruse for the comprehension of youth, till they have made very considerable proficiency in other branches of natural philosophy. The *velocity* of light is however so admirably calculated to impress the young mind, that I could not resist making the following extract from Dr. Thomson's System of Chymistry:—

"It has been demonstrated that light takes about eight minutes in moving across one half of the earth's orbit; consequently it moves at the astonishing rate of 200,000, miles in a second; therefore, if each of its particles weighed the thousandth part of a grain, its force would be greater than that of a bullet discharged from a musket. Were it even the millionth part of a grain in weight, it would destroy every thing against which it struck. If it even weighed the millionth part of *that*, it would still have a very sensible force. But how much less must be a particle of light, which makes no sensible impresion upon so delicate an organ as the eye? We are certain then that no particle of light can weigh $\frac{1}{1,000,000,000,000}$th of a grain*." See page 236.

"LET THERE BE LIGHT," the great Creator said,
His word the active child obey'd;
Awhile the Almighty wond'ring view'd,
And then himself pronounc'd it good.

YALDEN.

XXII. *Of the Nature and Formation of Nitre.*

The greatest part of the nitre we have is brought from the East Indies. See page 155. Should this supply fail, it may, after the example of the French, be formed artificially in Europe. During the second and third years of the Frenc[illegible]lic, the government required every district to send two intelligen[illegible]sons to Paris. This convocation, consisting of nearly eleven

‡ Thomson's Chymistry.

hundred individuals, received regular instruction from their first chymists partly concerning the manufacture of cannon, and partly concerning the making of salt-petre for gunpowder. This body of pupils was afterwards distributed among the different establishments in proportion to their abilities, and salt-petre was soon furnished by them in abundance. Ann. de Chim. xx. 298.

It is suspected that the French in this unexpected production of nitre availed themselves of a discovery of our countryman Dr. Milner, who formed nitrous acid by passing ammonia over oxide of manganese placed in a tube, and submitted to a red heat.

The theory of the formation of nitre was little known till lately. An admirable paper on the subject, by Chaptal, occupying 47 pages, may be seen in the Annales de Chimie, tom. xx. Annexed is an useful paper on the refining of saltpetre. Also a paper by Guyton on the same subject, tom. xxiii. of the same work.

A great quantity of nitre is used by the makers of oil of vitriol. It is ground small, and mixed with sulphur in order to afford oxygen to the sulphur while burning. For the same purpose it was used by the ancients in that destructive composition of antiquity, called the *Greek-fire*. Sulphur, resin, alcohol, camphor, and other combustibles were melted with it, and in this melted mass woollen cords were dipped, which were afterwards rolled up for use. These balls being set on fire were thrown into the tents, &c. of the enemy; and as the combustibles were furnished with a constant supply of *oxygen* from the nitre, nothing could extinguish them.

When Constantinople was attacked in the reign of Leo, many of the ships of the besiegers were destroyed by this chymical composition. For many centuries the method of making this dreadful article of destruction was lost; but it has just been re-discovered by the librarian of the elector of Bavaria, who has found a very old Latin manuscript which contains directions for preparing it.

XXIII. *Of Muriate of Lead.*

Muriate of lead, which is readily made, will afford the pupil a pleasing example of metallic crystallization. Take common red litharge, pour over it one-third of its weight of good strong muriatic acid, and stir it well with the litharge. When it has stood to become dry, melt it in a crucible, and pour it into a metallic vessel in a state of fusion. The cooled mass will be of a beautiful brilliant yellow, and when broken will exhibit the most regular crystallization that can be conceived. See page 162.

XXIV. *Of the Uses of Alum.*

The employment of alum in the arts is very extensive. It is used in dyeing, to fix a variety of vegetable colours, which otherwise would be fugitive. By means of this salt we are enabled to obtain the admired colour* of the ancients, called the Tyrian purple, which on pain of death none but the Cæsars could wear. It is of service in the manufacturing of candles, giving consistence and firmness to the tallow. It is employed in the cod-fisheries, when the fish are prepared for drying, having the property of preventing the salt from deliquescing. In the art of tanning it gives a firmness to the skins after they have become flaccid in the lime pits. It is used also in other preparations of leather. Its efficacy in preventing the bad effects of damp atmospheric air on preserved fish has been mentioned: with the same design it has been used in preparing paper for the preservation of gunpowder; and when used thus, it is of further service, by preserving the paper from readily taking fire. But one of the most striking advantages of this important salt is in

* See Introduction to Berthollet on Dyeing, page 19.

the preparation of acetate of alumine for the calico-printers; an article which, in the present improved state of the arts, the manufacturer cannot dispense with. It is prepared with acetate of lead, by a double decomposition. An easy way to prepare it is related in Rees's *new* Cyclopædia.

XXV. *Of Carbon and its Combinations.*

Carbon, whether we regard it in its most simple state, the diamond, or in that of common charcoal, is not only indestructible by age, but in all its combinations, which are infinitely beyond our comprehension, still preserves its identity. In the state of carbonic acid it exists in union with earths and stones in unbounded quantities; and though buried for thousands of years beneath immense rocks, or in the centre of mountains, it is still carbonic acid; for no sooner is it disengaged from its dormitory than it rises with all the life and vigour of recent formation, not in the least impaired by its torpid inactivity during a lapse of ages. Is not the consideration of this subject calculated to afford a strong and satisfactory analogical argument in favour of human resuscitation?

XXVI. *Of the Manufacture of Shot.*

The manufacture of small shot is curious, and will probably amuse the young reader. In melting the lead a small quantity of arsenic is added, which disposes it to run into spherical drops. When melted, it is poured into a cylinder whose circumference is pierced with holes. The lead streaming through the holes, soon divides into drops which fall into water, where they congeal. They are not all spherical; therefore, those that are must be separated, which is done by an ingenious contrivance. The whole is sifted on the upper end of a long smooth inclined plane, and the grains roll down to the lower end. But the pear-like shape of the bad grains makes them roll down irregularly, and they waddle as it were to a side; while the round ones run straight down, and are afterwards sorted into sizes by sieves. The manufacturers of the patent shot have fixed their furnace, for melting the metal, at the top of a tower 100 feet high, and procure a much greater number of spherical grains, by letting the melted lead fall into water from this height, as the shot is gradually cooled before it reaches the water*." See pages 214, and 282.

XXVII. *Sympathetic Ink.*

A mixture of muriate of ammonia and sulphate of copper in equal proportions, dissolved in water, will produce a sympathetic ink equal to Hellot's. It is of a bright yellow colour when warm, and of a beautiful emerald green when cold. Journal des Mines, No. 58. See page 225.

XXVIII. *Of the Manufacture of White Lead.*

Most of the manufactures of white lead are conducted somewhat similar to the method related at page 234; but for some purposes *sulphate of lead* answers as well, and it is now very often substituted for ceruse. At Tipton, near Dudley, there is a very large establishment for the preparation of white lead on a different principle. Muriate of soda is there decomposed by means of litharge; and as the soda becomes disengaged, the muriatic acid combines with the litharge, and forms *muriate of lead*. I have reason to believe that carbonate of soda is employed for the decomposition of the latter muriate, and that from thence results the carbonate of lead, which is the product of the manufactory. The manufactories of earthen ware in the Staffordshire potteries are chiefly supplied with this lead. Great quantities of it [illegible]xported to America.

* Dr. Black.

XXIX. *Of Water-gilding.*

Some persons may be glad to be informed how the process of water-gilding is conducted. It is done by previously cleaning copper intended to be gilt, with sand and weak aqua-fortis; after which the plate is plunged in a diluted solution of mercury; the mercury leaves its solution and precipitates itself upon the copper: this causes the amalgam of gold, which is afterwards spread on the piece, to adhere. When the amalgam of gold is uniformly spread, the piece is heated on charcoal; which volatilizes the mercury, and leaves the gold on the copper. See pages 180, 197, 204. The method practised by the Birmingham manufacturers may be seen in a paper of Mr. Collard's, printed in the ninth volume of the Philosophical Magazine. The processes for other kinds of gilding may be seen in Gren's Chymistry.

XXX. *Of Tin and Tinned Plates.*

Tin is of use for covering copper and iron culinary utensils. See page 211 and 212. It is also employed in the formation of tin-plate. These are thin plates of rolled iron, which are covered with tin by the following process:—The iron plates, having been thoroughly cleaned by rubbing them with sand, are steeped in water for 24 hours, acidulated by bran or sulphuric acid. They are then made dry, and are gently heated in an oven, being first rubbed over with grease, to prevent oxidizement. In this state they are immersed in melted tin, which not only adheres to the surface, but in a great measure penetrates the whole plate*. For a more particular account of these processes consult La Grange, vol. ii. 80. There are two kinds of tin known in commerce, viz. *block* tin and *grain* tin. Block tin is procured from the common tin ore, and is usually cast in blocks of about 320 pounds weight; after which it is taken to the proper offices to be assayed, where it receives the impression of a lion rampant, which are the arms of the earl of Cornwall, and which are necessary to make it saleable. Grain tin is found in small particles, in what is called the *stream tin ore*. It appears to have been washed from its original bed in remote ages. This kind of tin owes its superiority not only to the purity of the ore, but to the care with which it is washed and refined. Tin when taken to be stamped pays a duty of four shillings per hundred weight to the duke. From hence a vast income accrues to the Prince of Wales. For a more full account of the management of the Cornish tin-mines, consult the sixth volume of Maurice's Indian Antiquities.

XXXI. *Wine Tests.*

We are told that fraudulent wine merchants have sweetened their wines and ciders by the addition of lead. Dr. Watson relates that it was at one time a common practice at Paris. He directs how it may be detected. See his Chymical Essays, vol. iii. page 369. Methods of detecting this and other adulterations of wine may be seen in Dr. Willich's Lectures on Diet and Regimen. The following is easy of application, and will be found effectual:—Equal parts of oyster-shells and sulphur may be heated together, kept in a white heat for 15 minutes, and, when cold, mixed with an equal quantity of cream of tartar; these are put into a strong bottle with common water to boil for an hour; and then decanted into ounce phials, adding 20 drops of muriatic acid to each. This liquor precipitates the least quantities of lead, copper, &c. from wines in a very sensible black precipitate. As iron might accidentally be contained in the wine, the muriatic acid is added to prevent its precipitation, and its being mistaken for the precipitate of lead†. See pages 213 and 214.

* Dr. Thomson. † Parkinson.

XXXII. *Native Copper.*

A mass of *native* copper has been found in a valley in the Brazils 2666 pounds weight. The description of it in the Memoirs of the Royal Academy of Sciences of Lisbon, is said to be very interesting, as the largest specimen of native copper that was before known weighs only ten pounds. Appendix to Monthly Review, vol. xxvii. N. S. 551.

XXXIII. *Tin Mines.*

Tin mines, as they deepen, often produce copper; and formerly, where they had occasion to raise this ore, it was thrown aside as of no value, under the name of *poder*. Those who live in the present more enlightened period, are profiting by the ignorance of their forefathers. This proves of what importance it is to determine, by chymical analysis, the nature of every substance which passes under the miner's observation. See page 204; also Taylor's History of Mining, in Cornwall.

XXXIV. *Of Iron.*

There are several ways of analysing iron ores. An easy method has been suggested by Dr. Higgins, viz. by noting the quantity of hydrogen gas that is given out, by treating them with the usual mixture of sulphuric acid and water. This method will give, with very little trouble, a good comparative analysis. One part sulphuric acid to 8 parts water is the proper proportion for use.

If an iron ore be suspected to contain sulphur, take two measures of the hydrogen gas produced by the iron ore in question, and add to them one measure of oxygen gas; then inflame these gases by electricity, and examine the water which is produced from their combustion. If litmus paper be reddened thereby, it is a proof that it is acidified, and that the ore contained sulphur—otherwise not.

Some valuable information on the manufacture of iron and steel, and on the methods of preparing coke, may be collected from a scarce duodecimo volume, by a Mr. Horne, entitled "An Essay on Iron and Steel." A quarto volume on the same subject, with engravings of furnaces, &c. has lately been imported by De Boffe, from Paris, which is well spoken of.

Iron is found in solution in many natural springs; it gives the character to all our chalybeate waters; besides which there are some springs which contain iron in combination with sulphuric acid. These are called vitriolated waters. There are several in the kingdom, but those at Shadwell, near London, and at Swansey, in Glamorganshire, I believe, are the most important.

This metal is deposited magnetic, and nearly in its metallic state, by the Bath waters, which hold it in solution by some peculiar power that has hitherto escaped all investigation. See Dr. Gibbes on the Bath waters.

XXXV. *Of the Iron Manufactories.*

Some idea of the extent and importance of the iron trade (see page 207) may be conceived from the following account of the iron works in South Wales:—"Merthyr Tydvil was a very inconsiderable village till the year 1755, when the late Mr. Bacon obtained a lease of the iron and coal mines of a district at least eight miles long, and four wide, for 99 years. Since then these mines have been leased by him to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The part occupied by Mr. Crawshay contains now the largest set of iron work- [illegible] kingdom. He employs constantly more than two thousand [illegible] d pays weekly in wages and other expenses of the

works, twenty-five thousand pounds. The number of smelting furnaces belonging to the different companies at Merthyr is about sixteen. Around each of these furnaces are erected forges and rolling-mills, for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvil has become the largest town in Wales, and contains more than twelve thousand inhabitants." Abridged from Malkin's Scenery, &c. of South Wales.

XXXVI. *Of the Diamond.*

"It will no doubt be demanded how it happens that pure carbon or diamond is so scarce, while its compounds in different states are so abundantly dispersed? To dispel the astonishment of those who might consider this a ground of distrust, I shall remind them that the aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumine; that iron exists every where, under every form, excepting in the state of purity, and that the existence of *native* iron is still doubtful. The wonder respecting the diamond consists only in the opposition between facts and our opinions; it disappears in proportion as we discover and appropriate the powers of nature to produce the same effects*." See page 192.

XXXVII. *Of the Indestructibility of Matter.*

That the Author of nature had so constituted the world that none of its elements should be subject to destruction, might have been supposed by the ancients; but, till the present advanced state of the science of chymistry, no *proof* of this interesting fact could have been adduced. This is one of the many instances of the tendency which this valuable science has to enlarge the mind. In addition to the facts which have been already noticed it may be remarked, that provision has been made even for the restoration of the fallen leaves of vegetables, which rot upon the ground, and which, to a careless observer, would appear to be lost for ever. Berthollet has shown by experiment, that whenever the soil becomes charged with such matter, the oxygen of the atmosphere combines with it, and converts it into carbonic acid gas. The consequence of this is, that this same carbon in process of time is absorbed by a new race of vegetables, which it clothes with a new foliage, and which is itself destined to undergo similar putrefaction and renovation to the end of time.

Link after link the vital chain extends,
And the long line of BEING never ends.

How insignificant do the most stupendous works of art appear, when compared with the beautiful simplicity of these masterpieces of Nature! See page 193.

XXXVIII. *Of the Formation of Iron.*

Dr. Darwin was of opinion that iron may have been formed by the decomposition of vegetable matters. In support of this he urged that the waters oozing from all morasses are chalybeate, and deposit their ochre on being exposed to the air; and that fern-leaves, and other parts of vegetables, are frequently found in the centre of the nodules of some iron ores. Notes to Botanic Gardin, part i. According to Mr. Kirwan, the lavas all contain one-fourth of iron.

* Thomson's Notes on Fourcroy.

XXXIX. *Of Pit-coal.*

Dr. Darwin was of opinion that our pit-coal has all been sublimed more or less from the clay with which it was at first formed, in the decomposition of morasses. But from the various changes which combustible substances undergo, it must be impossible to speak with certainty on this subject. Naphtha, which is found in great abundance in Persia, is as fluid and transparent as water; but when exposed to the air it becomes yellow, and then brown; its consistence is increased, and it passes into *petroleum*. Petroleum is found native in many countries, and by an exposure to the air becomes *mineral tar*. Mineral tar is also found native, which by exposure to the air passes into *mineral pitch* and *maltha*. By further induration this passes into asphaltum, which substance is likewise found native in many parts of the world. See Dr. Thomson. Common coal is a composition of some of these bitumens and charcoal. The French jet and the English cannel coal are both so hard that they are susceptible of polish, and are frequently wrought into trinkets.

XL. *Oxide of Iron.*

According to Mr. Chenevix, there are four oxides of iron, the first, or least degree of oxidizement being white, and progressively to green, black, and red, founded upon the different colours which minerals possess that contain iron. Dr. Thomson, however, thinks that this variety of colour results from the various combinations into which the two oxides of iron enter, difference of colour being a very uncertain mark of difference in the degree of metallic oxidizement.

XLI. *Of the Glow-worm.*

"The glow-worm is the wingless *female* of a beetle insect. The male is of a dusky hue, without much beauty or peculiarity of markings. The female is more like the larva or grub of a beetle, than a perfect full grown insect. The light, which is of a beautiful sulphur colour, proceeds from the three last rings of the body. See page 247. From the circumstance of the male being a winged animal, and the female not, it was necessary that some contrivance should be had recourse to for directing the rambler to his sedentary mate. What more beautiful, and at the same time sufficient, guide could possibly be contrived, than this self lighted hymeneal torch?" Skrimshire.

Thine is an unobtrusive blaze,
Content in lowly shades to shine;
How much I wish, while thus I gaze,
To make thy modest merit mine!

Mrs. Opie.

XLII. *Of Light produced from Combustibles.*

The existence of light as a constituent part of combustible bodies seems to have been proved by the experiments of Deiman, Paets, and others. These chymists, exposed a mixture of sulphur and zinc to a high temperature, without any substance being present from which they could derive oxygen. At the instant when the sulphur and zinc formed a *sulphure*, there was a vivid emission of light; and when the materials were afterwards examined, it was found that no oxidizement had taken place. See this more fully explained by Charles Portal, esq. Phil. Mag. xv. 207; also by Mr. John Thomson, in his Notes on Fourcroy, vol. i. 190.

XLIII. *Of Combustion.*

It is now generally allowed, that nothing contributes to support combustion in an ignited body but the portion of oxygen gas which exists in atmospheric air: it is found also that some substances require pure oxygen gas for their combustion. Thus rock crystal has been exposed to the most intense heat for a very long time, and has suffered nothing in its hardness, transparency, or any other quality; but when submitted to a stream of oxygen gas it has been used like other substances.

XLIV. *Of Vegetable Respiration.*

M. Saussure has shown, that when vegetables decompose carbonic acid gas they throw off only half of the oxygen, and that the whole of the carbon and the other half of the oxygen enter into the composition of the plant; and that the leaves absorb oxygen gas in darkness, and emit an equal quantity when exposed to the light; so that vegetation tends to corrupt the atmosphere in the night, and to purify it in the day. The roots, wood, and petals, perform no inspiration. Phil. Mag. vol. xx. 307.

XLV. *Vegetable Poison.*

In the royal cabinet of Louis the Sixteenth, at Paris, there were arrows whose points were steeped in the juice of so venemous a plant, that, though exposed to the air for many years, they will destroy in a few minutes, with the slightest puncture, the stoutest animal that exists. The blood of the victim, trifling as may be the wound, instantly congeals; but if a small quantity of sugar be immediately swallowed by him, the circulation is as quickly restored*. See page 17.

Nature, compell'd by a superior cause,
Now breaks her own eternal laws,
Now *seems* to break them, and obeys
Her sovereign king in different ways.

WATTS'S LYRICS.

XLVI. *Of the Means of purifying the Atmosphere.*

When we perceive that the Deity has not only given the vegetable creation organs for purifying the atmosphere of its superabundant hydrogen, nitrogen, and carbon, but that he has also provided an innumerable multitude of predatory insects, as nature's scavengers, to remove all noxious matter, and to convert to their own nourishment and support what would otherwise, by the exhalation of its putrid miasmata, in time totally destroy the whole animal world—we are charmed with the rich economy of nature, and are furnished with another beautiful instance of the omniscience and beneficence of its omnipotent Author. See page 52.

XLVII. *Of some of the Effects of Respiration.*

The oxygen of the atmosphere deprives the blood of carbon and hydrogen: with the first it forms carbonic acid, and with the latter water; both which are thrown from the lungs in the act of respiration. As carbonic acid has the property of sweetening putrid substances, by uniting chymically with putrid vapour, perhaps it operates in this way with regard to the putrid exhalations from the lungs, and renders the breath of some persons inoffensive, which would otherwise be intolerably fetid and pestilential†. See page 56.

* St Pierre's Studies of Nature, vol. i. 13.
† Dr. Lambe on Constitutional Diseases.

XLVIII. *Of Snow.*

Nature has furnished *snow* with the power of absorbing and combining with a large portion of oxygen; hence it improves land by lying upon it. The snow melting and penetrating into the softened earth communicates to it oxygen, and thus promotes the germination of seeds. The carbon of the earth combining with the oxygen is converted into carbonic acid, and thereby acquires more solubility; while the water contributes to excite that activity which had been rendered dormant in the roots by the cold. It is this property of carbon which deprives water of its superabundant oxygen, which would render it prejudicial to health, and unfit for the purposes of life. So that what would otherwise be injurious to us is improved by the ground, and at the same time gives power and activity to the mould*. See page 76.

The nature of snow being now understood, snow-water may be applied to many medicinal purposes, whenever the system is intended to be super-oxygenized. Hereafter it may possibly be employed in the arts.

XLIX. *Manufacture of Sugar.*

The sugar cane affords most of the sugar which is consumed in Europe. The ripe canes are crushed between two iron cylinders, placed perpendicularly. The expressed juice falls on a plate beneath, whence it flows into a caldron, where it is boiled with wood-ashes and lime, and the scum taken off. This boiling with ashes and lime is repeated in three other boilers, and converts it into syrup. It is then strongly boiled with lime and alum, and when sufficiently concentrated is poured into hogsheads pierced at the bottom with many holes, to let off the molasses, which will not crystallize. These holes are afterwards stopped with canes, as we see them when imported. The sugar, as it cools, becomes solid in the casks, and is called *muscovado* sugar. It afterwards undergoes several refinings in order to form it into loaf sugar. See Thomson's Fourcroy, 1800, vol. iii. 116.

It should be remembered that oxygen is absolutely necessary for the formation of sugar. Sugar is a vegetable oxide. If sugar were deprived of the greatest part of its oxygen it would lose it sweetness, and would be no longer sugar, but a kind of gummy substance, possessing properties more analogous to gum than sugar. Mr. Cruickshank has effected this change in sugar by means of phosphuret of lime, which has a very strong attraction for oxygen, though he was not able to reproduce sugar by the union of gum with oxygen. See pages 103 and 191. See also an account of these experiments in Dr. Rollo's Treatise on Diabetes.

L. *Of Boracic Acid.*

The boracic acid is found dissolved in several lakes of Tuscany. In the waters of the lake Cherchiago, near Monterotondo, in the province of Sienna, this acid exists in sufficient abundance to be advantageously converted into borax, by soda. Fabroni, a chymist of eminence at Florence, asserts that this acid is a modification of the muriatic, and that it may be totally formed by means of the latter acid. See page 136.

LI. *Of the Affinities of Oxygen.*

With the exception of caloric, oxygen seems to take the lead of all substances by the extent and energy of its affinities. See pages 122 and 248. As it has a great disposition to elasticity, every elevation of temperature weakens its combination with solid bodies. The two properties which particularly characterize oxygen are, first, that of combining with substances

* Driessen on the Nature of Snow.

which are inflammable, and which cease to be so by the combination; second, that of communicating acidity to the combinations which it forms, when it does not experience too great a degree of saturation.

Strong affinity for oxygen may be attributed to those substances which can vanquish and combine with a large quantity of it without becoming acids. Hydrogen holds the first place in this respect. Berthollet.

LII. *Of the Uses of Diamond.*

The lapidaries use a considerable quantity of diamond, which they pulverise in iron mortars, and employ in that state, with steel instruments, to divide pebbles and precious stones. These small pieces of diamond are worth 28 shillings a carat. The use of the diamond in this way is very extensive. Had nature withheld the diamond,—the pebble, the agate, and a variety of other stones, would have been of little value, as no other substance is hard enough to operate upon them. In this way rock crystal from Brazil is divided into leaves, and ground and polished with diamond dust for spectacles, and other optical instruments. See page 180.

LIII. *Of the Effect of Oxygen upon Colours.*

Several of the effects of oxygen have been mentioned in different parts of this work; but its action on colouring substances has not been noticed, though it is various and striking. When woollen cloths are taken out of an indigo vat, they are of a full green colour; but they are scarcely exposed to the atmospheric air a minute, before they imbibe a sufficient portion of oxygen to change the colour to a deep blue. In like manner the whelk (the buccinum of Linnæus), which is used to dye purple, undergoes as extraordinary a change. The liquor, though naturally yellow, becomes oxidized by exposure to the sun and air, passes through various shades of yellow, green, crimson, &c. and at length assumes that colour so precious in the eyes of the ancients. A good *black* cannot be given to cloth without frequent exposure to the air. Light has a great affinity for oxygen: hence clothes frequently fade and lose their colours by the abstraction of oxygen. That part of the furniture of a bed which has been exposed to the sun will often be entirely faded, while the parts which have not been so exposed will retain their original colours. All this arises from the same cause; for the oxygen which existed in a solid form is rendered aëriform by the rays of the sun, and goes off in the state of oxygen gas. See page 246.

LIV. *Of the Gases emitted in Respiration.*

Having shown that sheet of the work which contains page 59 to a friend of mine, an ingenious chymist, he suggested that those remarks on the *levity* of nitrogen gas evolved from the lungs in respiration, would have more force were I to contrast this character with the superior specific gravity of carbonic acid gas, wich is ejected at the same instant. For during that *remarkable* interval that always occurs in breathing, there is sufficient time allowed for these noxious fluids to separate; the first to ascend, while the other preponderates, leaving a space for a fresh current of uncontaminated atmospheric air. Thus every thing is prepared without any care or forethought of ours for a new inspiration.

The air inhal'd is not the gas
That from a thousand lungs reeks back to thine
Sated with exhalations rank and fell,
Which, drunk, would poison the balsamic blood,
And rouse the heart to ev'ry fever's rage—
But air that trembling floats from hill to hill,
From vale to mountain, with incessant change
Of purest element.

ARMSTRONG.

LV. *Of Lutes.*

Glazier's putty is a very good lute for all common purposes, but it is necessary that the whiting be made thoroughly dry before it is mixed with the oil.

Dr. Black recommends a mixture of four parts sand, and one of clay, except where it is to be exposed to an intense heat, and in such situations to use six of sand to one of clay.

For *fire*-lute Mr. Watt directs the use of porcelain clay from Cornwall (not pipe-clay), to be pounded small, and mixed up to the consistence of thick paint, with a solution of two ounces of borax in a pint of hot water. For want of this peculiar kind of clay, slacked quick-lime, mixed up in the same manner, may be used. This may be kept ready mixed in a covered vessel. For *cold*-lute he directs to take equal parts by measure of the above clay and wheat flour, and to mix them to a proper consistence with cold water. This is more tenacious than his fire lute, but does not keep so well.

A very excellent lute for most purposes may be made by beating up an egg, both the white and the yolk, with half its weight of quick-lime in powder. This lute is to be put upon a piece of linen, and applied as usual. It dries slowly, but becomes very compact, and acquires great hardness.

LVI. *Of Distillation.*

Some important directions for the management of different kinds of distillation may be seen in a paper of the thirteenth volume of the Repertory of Arts, which gives a very particular account of the management of these processes of Petersburgh.

LVII. *Of Gypsum, commonly called Plaster of Paris.*

The property which sulphate of lime has of setting into a compact mass when mixed up with water was well known to the ancients. Herodotus informs us of a curious method, by which the inhabitants of Ethiopia preserved the remembrance of their deceased relatives. They had the custom, he says, of drying the body in the sun, then covering it with a paste of gypsum, and of painting the portrait of the deceased upon the plaster. See page 166.

LVIII. *Of the extreme Hardness of Ice in some Countries.*

The following narration will show the solidity that water is capable of acquiring when divested of a large portion of its caloric:—During the severe winter of 1740, a palace of ice, fifty-two feet long, sixteen feet wide, and twenty high, was built at Petersburgh, according to the most elegant rules of art. The river Neva afforded the ice, which was from two to three feet thick, blocks of which were cut, and embellished with various ornaments. When built up, the different parts were coloured by sprinkling them over with wa[illegible] various tints. Six cannons made of, and mounted with, ice, with w[illegible] same matter, were placed before the palace; and a hempen

let was driven by one of these cannon, in the presence of the whole
rt, through a board two inches thick, at the distance of sixty paces*.
page 89.

No forest fell,
Imperial mistress of the fur-clad Russ,
When thou wouldst build—no quarry sent its stores
T' enrich thy walls: but thou didst hew the floods,
And make thy marble of the glassy wave.
Silently as a dream the fabric rose;
Ice upon ice the well adjusted parts
Were soon conjoined; nor other cement ask'd
Than water interfus'd to make them one.
Lamps gracefully disposed, and of all hues,
Illumin'd ev'ry side. Long wavy wreaths
Of flowers, that fear'd no enemy but warmth,
Blush'd on the pannels, which were once a stream,
And soon to slide into a stream again.

COWPER.

* M. de Bomare.

TABLES.

A table of Carats, with their corresponding Degrees of Specific Gravities, for ascertaining the Specific Gravities of Alkaline Lees, or other Fluids, heavier than Water.

Carats.	Sp. Grav.	Carats.	Sp. Grav.	Carats.	Sp. Grav.	Carats.	Sp. Grav.
1 =	1.0078	33 =	1.2578	65 =	1.5078	97 =	1.7578
2	1.0156	34	1.2656	66	1.5156	98	1.7656
3	1.0234	35	1.2734	67	1.5234	99	1.7734
4	1.0312	36	1.2812	68	1.5312	100	1.7821
5	1.0390	37	1.2890	69	1.5390	101	1.7890
6	1.0468	38	1.2968	70	1.5468	102	1.7968
7	1.0546	39	1.3046	71	1.5546	103	1.8046
8	1.0625	40	1.3125	72	1.5625	104	1.8124
9	1.0703	41	1.3203	73	1.5703	105	1.8202
10	1.0781	42	1.3281	74	1.5781	106	1.8280
11	1.0859	43	1.3359	75	1.5859	107	1.8358
12	1.0937	44	1.3437	76	1.5937	108	1.8436
13	1.1015	45	1.3515	77	1.6015	109	1.8514
14	1.1093	46	1.3593	78	1.6093	110	1.8593
15	1.1171	47	1.3671	79	1.6171	111	1.8671
16	1.1250	48	1.3750	80	1.6250	112	1.8750
17	1.1328	49	1.3828	81	1.6328	113	1.8828
18	1.1406	50	1.3906	82	1.6406	114	1.8906
19	1.1484	51	1.3984	83	1.6484	115	1.8984
20	1.1562	52	1.4062	84	1.6562	116	1.9062
21	1.1640	53	1.4140	85	1.6640	117	1.9140
22	1.1718	54	1.4218	86	1.6718	118	1.9218
23	1.1796	55	1.4296	87	1.6796	119	1.9296
24	1.1875	56	1.4375	88	1.6875	120	1.9375
25	1.1953	57	1.4453	89	1.6953	121	1.9453
26	1.2031	58	1.4531	90	1.7031	122	1.9531
27	1.2109	59	1.4609	91	1.7109	123	1.9609
28	1.2187	60	1.4687	92	1.7187	124	1.9687
29	1.2265	61	1.4765	93	1.7265	125	1.9765
30	1.2343	62	1.4843	94	1.7343	126	1.9843
31	1.2421	63	1.4921	95	1.7421	127	1.9921
32	1.2500	64	1.5000	96	1.7500	128	2.0000

For an account of the principle on which this table is constructed, see Additional Notes, No. 1.

Table of the Degrees of different Thermometers (omitting fractions) at which some chymical Phænomena occur.

	Fahr.	Reau.	Cent.	Wedg.
Cold produced by Mr. Walker	— 90	— 54	— 68	
Nitric acid freezes	— 66	— 44	— 55	
Mercury freezes	— 39	— 32	— 39	
Brandy freezes	— 7	— 17	— 14	
Cold produced by mixing equal parts of snow and muriate of soda	0	— 14	— 18	
Strong wines freeze	20	— 5	— 6	
Water freezes	32	0	0	
Vinous fermentation begins	59	12	15	
Ditto rapid, and acetous begins	77	20	25	
Acetous fermentation ceases	88	25	31	
Ether boils	98	29	36	
Spermaceti melts	112	36	45	
Tallow melts	127	42	53	
Ammonia separates from water	130	44	54	
Bees' wax melts	142	49	61	
Camphor sublimes	145	50	63	
Bleached wax melts	155	55	69	
Sulphur evaporates	170	61	77	
Alcohol boils	176	64	80	
Water boils	212	80	100	
Sulphur melts	234	89	111	
Nitrous acid boils	242	93	116	
Sulphur burns slowly	303	120	150	
Tin melts	442	182	227	
Sulphuric acid boils	590	248	310	
Lead melts	612	258	325	
Mercury boils	660	279	350	
Zinc melts	700	297	371	
Iron a bright red in the dark	750	315	384	
Hydrogen gas burns	800	341	427	
Iron red in the twilight	884	380	475	
——— red hot in a common fire	1050	448	560	
——— red heat in day light	1077	462	577	1
Enamel colours burnt	1807	737	986	6
Diamond burns	2897	1451	1814	14
Brass melts	3807	1678	2100	21
Copper melts	4587	2024	2530	27
Silver melts	4717	2082	2602	28
Gold melts	5237	2313	2780	32
Delft ware fired	6507	2880	3580	40
Cream-coloured stone ware fired	12257	5370	6770	86
Flint glass furnace greatest heat	15897	7025	8770	114
Smith's forge	17327	7650	9600	125
Cobalt melts—Cast iron melts	17977	7975	9850	130
Nickel melts	20577	9131	11414	150
Iron melts	21637	9602	12001	158
Manganese melts	21877	9708	12136	160
Platina melts	23177	10286	12857	170
Greatest heat observed	25127	11100	13900	185

Table of Freezing Mixtures.—From Mr. Walker's Papers in the Philosophical Transactions.

A Mixture of	Parts.	Reduces the temperature.
Sulphate of soda	8	from 50° to 0°
Muriatic acid	5	
Snow	1	from 32° to 0°
Muriate of soda	1	
Snow	2	from 0° to —5°
Muriate of soda	1	
Snow	1	from —5° to —18°
Muriate of soda	5	
Muriate of ammonia and nitrate of potash of each	5	
Snow	1	from 20° to—60°
Diluted sulphuric acid	1	
Snow	1	from —40° to —73°
Muriate of lime	3	
Snow	8	from —68° to —91°
Diluted sulphuric acid	10	

The salts ought to be fresh crystallized, and reduced to very fine powder, and the mixtures made in thin vessels as quickly as possible.

Numerical Expression of Chymical Affinities.——By M. Morveau.

	Sulphuric Acid.	Nitrous Acid.	Muriatic Acid.	Acetous Acid.	Carbonic Acid.
Barytes	65	62	36	29	14
Potash .	62	58	32	26	9
Soda	58	59	28	25	8
Lime	54	44	20	19	2
Ammonia	46	38	14	20	4
Magnesia	50	40	16	17	6
Argil	40	36	10	15	2

Note. The above table, showing the comparative force of attractions between the aforesaid bodies, may be useful to point out the probability of any particular decomposition, previous to the attempt being made.

Table of the Boiling Point of sundry Liquids, &c.

Ether	98	Phosphorus .	554
Aqua ammonia . .	140	Oil turpentine .	560
Alcohol . . .	176	Sulphur . .	570
Water . . .	212	Sulphuric Acid .	590
Muriate of lime . .	230	Linseed oil .	600
Nitric acid . . .	248	Mercury .	660

Table of the quantity of real Acid taken up by Alkalies and Earths.—By Mr. Kirwan.

100 Parts.	Sulphuric.	Nitric.	Muriatic.	Carbonic.
Potash .	82,48	84,96	56,30	105
Soda .	127,68	135,71	73,41	66,80
Ammonia .	383,80	247,82	171	Variable
Barytes .	50	56	31,80	282
Strontian .	72,41	85,56	46	43,20
Lime .	143	179,50	84,49	81,81
Magnesia .	172,64	210	111,35	200
Alumine .	150,90	. .	. .	335

Table of the Quantity of Alkalies and Earths taken up by 100 Parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, when saturated.—By Mr. Kirwan.

100 Parts.	Potash	Soda.	Ammo.	Barytes.	Stron.	Lime.	Magnesia.
Sulphuric	121,48	78,32	26,05	200	138	70	57,92
Nitric	117,70	73,03	40,35	178,12	116,86	55,70	47,64
Muriatic	177,60	136,20	58,48	314,46	216,21	118,30	898
Carbonic	95,10	149,60	. .	354,50	231	122	50

Table of the component Parts of Salts.—By Mr. Kirwan.

Salts.	Baſis.	Acid.	Water.	State.
Pearl ash . .	60	30	6	Dry
Carbonate of potaſh .	41	43	16	Cryſtallized
———— ſoda .	21,58	14,42	64	Fully cryſtallized
———— ſoda .	59,86	40,05	. .	Deſiccated
———— barytes .	78	22	. .	Natural
———— ſtrontian .	69,5	30	. .	Natural
———— lime . .	55	45	. .	Natural and pure
———— magneſia .	25	50	25	Cryſtallized
———— common do. .	45	34	21	Dried at 80°
Sulphate of potaſh .	54,08	45,02	. .	Dry
———— ſoda .	18,48	23,52	58	Fully cryſtallized
———— ſoda .	44	56	. .	Deſiccated at 700°
———— ammonia .	14,24	54,66	31,1	
———— barytes .	66,66	33,33		Natural
———— ſtrontian .	58	42	.	Natural
———— lime .	32	46	22	Dried at 66°
———— lime .	35,23	50,39	14,38	Dried at 170°
———— lime .	38,81	55,84	5,35	Ignited
———— lime .	41	59	. .	Incandeſcent
———— magneſia .	17	29,35	53,65	Fully cryſtallized
———— magneſia .	36,68	63,32	. .	Deſiccated
Alum . .	31,24 & wat.	17,66	51	Cryſtallized
Alum . .	63,75	36,25	. .	Deſiccated at 700°
Nitrate of potaſh .	51,8	44	4,2	Dried at 70°
———— ſoda .	40,58	53,21	6,21	Dried at 400°
———— ſoda .	42,34	57,55	. .	Ignited
———— ammonia .	23	57	20	
———— barytes .	57	32	11	Cryſtallized
———— ſtrontian .	36,21	31,07	32,72	Cryſtallized
———— lime .	32	57,44	10,56	Well dried in air
———— magneſia .	22	46	22	Cryſtallized
Muriate of potaſh .	64	36	. .	Dried at 80°
———— ſoda .	53	47 & wat.	. .	Dried at 80°
———— ammonia .	. .	. .	. .	Cryſtallized
———— ammonia .	25	42,75	32,25	Sublimed
———— barytes .	64	20	16	Cryſtallized
———— barytes .	76,2	23,8	. .	Deſiccated
———— ſtrontian .	40	18	42	Cryſtallized
———— ſtrontian .	69	31	. .	Deſiccated
———— lime .	50	42	8	Red hot
———— magneſia .	31,07	34,59	34,34	Senſibly dry

A TABLE of the PROPERTIES of several of the SALTS, arranged in each class according to the Affinities of their Radicals for the Acids.

Salts.	Origin.	Taste.	Form of their Crystals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water.	
						60°	Boiling.
Sulphate of barytes	Native	None		None	Decrepitates	Insoluble	Insoluble
—— potash	Artificial	Bitter and acrid	Six-sided prisms	Ditto	Ditto	6	20
—— ditto super	Ditto	Sharp and hot	Ditto	Little	Fusible	50	100
—— soda	In sea water	Bitter and cool	Ditto grooved	Effloresces	Aqueous fusion	20	45
—— strontian	Native	None	Needles interfecting each other	None	Fusible at a high temperature	Insoluble	Insoluble
—— lime	Ditto	Hardly perceptible	Quadrangular prisms	Ditto	Calcines and melts	Nearly inso.	Nearly inso.
—— ammonia	Artificial		Six-sided prisms	Little	Aqueous fusion	50	50 little more
—— magnesia	In sea water	Bitter and cool	Four-sided ditto, ending in pyramids	Slightly efflorescent	Ditto	100	133
—— ditto and ammonia	Artificial	Ditto and acrid	Octahedrons	None	Ditto	Little solu.	Little soluble
—— alumine super	Ditto	Astringent	Thin pearly crystals	Little	Dries to powder	Moderately	Moderately
—— ditto and potash	Ditto	Ditto and styptic	Octahedrons	Ditto	Melts and dries	5	75
Sulphite of barytes	Ditto	Little	Tetrahedrons	Ditto		Insoluble	Insoluble
—— lime	Ditto	Sulphureous	Six sided prisms	Effloresces	Dries to powder	$\frac{1}{8}$th of a part	
—— potash	Ditto	Ditto sharp and acrid	Various	Ditto	Decrepitates	100	Still more
—— soda	Ditto	Ditto and cool	Four-sided prisms	Ditto	Watery fusion	25	100
—— ammonia	Ditto	Cool	Six-sided ditto, and various	Deliquesces	Decrepitates	100	
—— magnesia	Ditto	Sweet and earth	Flat transparent tetrahedrons	Effloresces	Softens and dries	5	
—— alumine	Ditto	Sulphureous and earthy	In white powder	Changes to sulphate	Decomposes	Insoluble	Insoluble

Salts.	Origin.	Taſte.	Form of their Cryſtals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water. 60°	Boiling.
Nitrate of barytes	Artificial	Hot, acrid, and rough	Octahedrons and plates	Little	Decrepitates	9	30
—— potaſh	Native	Cool and bitter	Various	None	Melts	14	200
—— ſoda	Artificial	Ditto	Rhomboidal cubes	Softens	Decrepitates	33	100
—— ſtrontian	Ditto	Cool and penetrating	Octahedrons	None	Ditto	20	
—— lime	Ditto and native	Acrid, hot, and bitter	Six-ſided priſms	Deliqueſces	Fuſes and decompoſes	400	Still more
—— ammonia	Artificial	Acrid and bitter	Various	Ditto	Watery fuſion	50	200
—— magneſia	From mother waters of nitre	Bitter	Small needles and four-ſided priſms	Ditto	Fuſible	100	
—— of alumine	Artificial	Aſtringent	Does not cryſtallize	Ditto	Decompoſes	Extremely Soluble	
Muriate of barytes	Ditto	Pungent	In tables and octagons	Unalterable	Decrepitates	18	
—— potaſh	Ditto	Pure ſaline taſte	Cubes	Moiſtens a little	Ditto	33	
—— ſoda	Sea and rocks	Ditto	Ditto	Ditto and dries again	Ditto	35	36
—— ſtrontian	Artificial	Pungent	Fine priſms	Unalterable	Melts	120	
—— lime	Mineral waters	Ditto	Needle-like ditto	Very deliqueſcent	Ditto	200	
—— ammonia	Native	Bitter	Various	None	Fuſible and volatile	30	100
—— magneſia	In waters	Ditto and diſagreeable	In powder, or jelly	Deliqueſces	Ditto and decompoſes	100	
Oxygenized muriate of potaſh	Artificial	Cool and harſh	Square thin plates	None	Ditto and ditto	5	33
Phoſphate of barytes	Ditto	Inſipid	Heavy powder	Ditto	Fuſible in great heat	Inſoluble	Inſoluble
—— ſtrontian	Ditto	Ditto	White ditto	Ditto	Ditto	Ditto	Ditto
—— lime	Native	Ditto	Various priſms	Ditto	Do. with difficulty	Ditto	Ditto
—— ditto ſuper	Artificial	Sour	Plates or ſilky threads	Moiſtens a little	Softens and dries		
—— ſoda	Ditto	Mild, ſaline	Various	Effloreſces outwardly	Aqueous fuſion	25	50

(Table continued.)

Salts.	Origin.	Taſte.	Form of their Cryſtals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water. 60°	Boiling.
Phoſphate of ammonia	Artificial	Salt and urinous	Four ſided-priſms ending in pyramids	None	Aqueous fuſion	25	50 rather more
——— ditto and ſoda	In urine			Effloreſces			
Phoſphite of lime	Artificial	Acid	Small needles	None	Decompoſes	Sparingly	
——— barytes	Ditto	Inſipid	White powder	Ditto	Melts	Ditto	
——— magneſia	Ditto	Ditto	Flaky cryſtals	Effloreſces	Ditto	$\frac{1}{4}$th of a part	
——— potaſh	Ditto	Sharp	Four-ſided priſms	Little	Decrepitates and melts	33	
——— ſoda	Ditto	Mild and cool	Irregular ditto	Effloreſces	Melts	50	50
——— ammonia	Ditto	Sharp	Needles and priſms	Deliqueſces	Ditto and decompoſes	50	
Fluate of lime	Native	None	Various	None	Decrepitates	Inſoluble	
——— ſoda	Artificial	Bitter	Cubes	Ditto	Ditto	Difficult	
Borate lime	Ditto and native	Inſipid	White powder			Ditto	
——— ditto and magneſia	Native	Ditto	Polyhedron with 22 faces	None	Decrepitates	Inſoluble	
——— ſoda	Ditto	Alkaline and ſweet	Irregular	Effloreſces	Aqueous fuſion	$8\frac{1}{4}$	17
Carbonate of barytes	Ditto		Striated maſſes	None	Fuſes	Nearly inſo.	
——— ſtrontian	Ditto	None	Striated priſms	Ditto	Ditto and decompoſes	Ditto	
——— lime	Ditto	None	Various	Ditto	Decrepitates	Inſoluble	
——— potaſh	Ditto and artificial	Urinous	Squareprifms terminated by ſquare pyramids	Cryſtals effloreſce	Aqueous fuſion	25	80
——— ſoda	Native	Ditto	Irregular octahedrons	Ditto much	Ditto	50	100
——— magneſia	Artificial	None	Small priſms	Ditto	Decrepitates	2	If cryſtallised
——— ammonia	Ditto	Little acrid	Irregular	Unalterable	Sublimes	50	100

TABLE OF BAUMÉ'S HYDROMETERS.

Baumé's Hydrometer for Vinous Spirits. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
10	= 1.000	21	= —.922	31	= —.861
11	—.990	22	—.915	32	—.856
12	—.985	23	—.909	33	—.852
13	—.977	24	—.903	34	—.847
14	—.970	25	—.897	35	—.842
15	—.963	26	—.892	36	—.837
16	—.955	27	—.886	37	—.832
17	—.949	28	—.880	38	—.827
18	—.942	29	—.874	39	—.822
19	—.935	30	—.867	40	—.817
20	—.928				

Baumé's Hydrometer for Salts and Acids. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
0	1.000	27	1.230	51	1.547
3	1.020	30	1.261	54	1.594
6	1.040	33	1.295	57	1.659
9	1.064	36	1.333	60	1.717
12	1.089	39	1.373	63	1.779
15	1.114	42	1.414	66	1.848
18	1.140	45	1.455	69	1.920
21	1.170	48	1.500	72	1.000
24	1.200				

Table of the Quantities of Acids and Bases which mutually neutralize each other: calculated by Berthollet from the New Tables published by Richter.

Bases.		Acids.	
Alumine . .	525	Fluoric .	427
Magnesia .	615	Carbonic .	577
Ammonia .	672	Sebacic .	706
Lime .	793	Muriatic .	712
Soda .	859	Oxalic .	755
Strontian .	1329	Phosphoric .	979
Potash .	1605	Formic .	988
Barytes .	2222	Sulphuric .	1000
		Succinic .	1209
		Nitric .	1405
		Acetic .	1480
		Citric .	1683
		Tartareous .	1694

Note. The intention of this table is, that if an article in one of these two columns is taken....for example, potash....to which the number 1605 corresponds, the numbers of the other column will show how much of each acid is required to neutralize these 1605 parts of potash: viz. they will require, 427 parts of fluoric acid, or 577 of carbonic acid, or 1480 of acetic acid, &c. In like manner, if an article of the second column be taken, the first column will show how much earth or alkali will neutralize it. By means of the rule of three, this table may be applied to any quantity of either of the above substances.

TABLES.

A table of Carats, with their corresponding Degrees of Specific Gravities, for ascertaining the Specific Gravities of Alkaline Lies, or other Fluids, heavier than Water.

Carats.	Sp. Grav.	Carats.	Sp. Grav.	Carats.	Sp. Grav.	Carats.	Sp. Grav.
1 =	1.0078	33 =	1.2578	65 =	1.5078	97 =	1.7578
2	1.0156	34	1.2656	66	1.5156	98	1.7656
3	1.0234	35	1.2734	67	1.5234	99	1.7734
4	1.0312	36	1.2812	68	1.5312	100	1.7821
5	1.0390	37	1.2890	69	1.5390	101	1.7890
6	1.0468	38	1.2968	70	1.5468	102	1.7968
7	1.0546	39	1.3046	71	1.5546	103	1.8046
8	1.0625	40	1.3125	72	1.5625	104	1.8124
9	1.0703	41	1.3203	73	1.5703	105	1.8202
10	1.0781	42	1.3281	74	1.5781	106	1.8280
11	1.0859	43	1.3359	75	1.5859	107	1.8358
12	1.0937	44	1.3437	76	1.5937	108	1.8436
13	1.1015	45	1.3515	77	1.6015	109	1.8514
14	1.1093	46	1.3593	78	1.6093	110	1.8593
15	1.1171	47	1.3671	79	1.6171	111	1.8671
16	1.1250	48	1.3750	80	1.6250	112	1.8750
17	1.1328	49	1.3828	81	1.6328	113	1.8828
18	1.1406	50	1.3906	82	1.6406	114	1.8906
19	1.1484	51	1.3984	83	1.6484	115	1.8984
20	1.1562	52	1.4062	84	1.6562	116	1.9062
21	1.1640	53	1.4140	85	1.6640	117	1.9140
22	1.1718	54	1.4218	86	1.6718	118	1.9218
23	1.1796	55	1.4296	87	1.6796	119	1.9296
24	1.1875	56	1.4375	88	1.6875	120	1.9375
25	1.1953	57	1.4453	89	1.6953	121	1.9453
26	1.2031	58	1.4531	90	1.7031	122	1.9531
27	1.2109	59	1.4609	91	1.7109	123	1.9609
28	1.2187	60	1.4687	92	1.7187	124	1.9687
29	1.2265	61	1.4765	93	1.7265	125	1.9765
30	1.2343	62	1.4843	94	1.7343	126	1.9843
31	1.2421	63	1.4921	95	1.7421	127	1.9921
32	1.2500	64	1.5000	96	1.7500	128	2.0000

For an account of the principle on which this table is constructed, see Additional Notes, No. 1.

Table of the Degrees of different Thermometers (omitting fractions) at which some chymical Phænomena occur.

	Fahr.	Reau.	Cent.	W edg.
Cold produced by Mr. Walker	— 90	— 54	— 68	
Nitric acid freezes	— 66	— 44	— 55	
Mercury freezes	— 39	— 32	— 39	
Brandy freezes	— 7	— 17	— 14	
Cold produced by mixing equal parts of snow and muriate of soda	0	— 14	— 18	
Strong wines freeze	20	— 5	— 6	
Water freezes	32	0	0	
Vinous fermentation begins	59	12	15	
Ditto rapid, and acetous begins	77	20	25	
Acetous fermentation ceases	88	25	31	
Ether boils	98	29	36	
Spermaceti melts	112	36	45	
Tallow melts	127	42	53	
Ammonia separates from water	130	44	54	
Bees' wax melts	142	49	61	
Camphor sublimes	145	50	63	
Bleached wax melts	155	55	69	
Sulphur evaporates	170	61	77	
Alcohol boils	176	64	80	
Water boils	212	80	100	
Sulphur melts	234	89	111	
Nitrous acid boils	242	93	116	
Sulphur burns slowly	303	120	150	
Tin melts	442	182	227	
Sulphuric acid boils	590	248	310	
Lead melts	612	258	325	
Mercury boils	660	279	350	
Zinc melts	700	297	371	
Iron a bright red in the dark	750	315	384	
Hydrogen gas burns	800	341	427	
Iron red in the twilight	884	380	475	
——— red hot in a common fire	1050	448	560	
——— red heat in day light	1077	462	577	1
Enamel colours burnt	1807	737	986	6
Diamond burns	2897	1451	1814	14
Brass melts	3807	1678	2100	21
Copper melts	4587	2024	2530	27
Silver melts	4717	2082	2602	28
Gold melts	5237	2313	2780	32
Delft ware fired	6507	2880	3580	40
Cream-coloured stone ware fired	12257	5370	6770	86
Flint glass furnace greatest heat	15897	7025	8770	114
Smith's forge	17327	7650	9600	125
Cobalt melts—Cast iron melts	17977	7975	9850	130
Nickel melts	20577	9131	11414	150
Iron melts	21637	9602	12001	158
Manganese melts	21877	9708	12136	160
Platina melts	23177	10286	12857	170
Greatest heat observed	25127	11100	13900	185

Table of Freezing Mixtures.—From Mr. Walker's Papers in the Philosophical Transactions.

A Mixture of	Parts.	Reduces the temperature.
Sulphate of soda . . .	8	from 50° to 0°
Muriatic acid . . .	5	
Snow	1	from 32° to 0°
Muriate of soda . . .	1	
Snow	2	from 0° to —5°
Muriate of soda . . .	1	
Snow	1	from —5° to —18°
Muriate of soda . . .	5	
Muriate of ammonia and nitrate of potash of each	5	
Snow	1	from 20° to—60°
Diluted sulphuric acid . .	1	
Snow	1	from —40° to —73°
Muriate of lime . . .	3	
Snow	8	from —68° to —91°
Diluted sulphuric acid . .	10	

The salts ought to be fresh crystallized, and reduced to very fine powder, and the mixtures made in thin vessels as quickly as possible.

Numerical Expression of Chymical Affinities.——By M. Morveau.

	Sulphuric Acid.	Nitrous Acid.	Muriatic Acid.	Acetous Acid.	Carbonic Acid.
Barytes	65	62	36	29	14
Potash .	62	58	32	26	9
Soda	58	59	28	25	8
Lime .	54	44	20	19	2
Ammonia	46	38	14	20	4
Magnesia	50	40	16	17	6
Argil	40	36	10	15	2

Note. The above table, showing the comparative force of attractions between the aforesaid bodies, may be useful to point out the probability of any particular decomposition, previous to the attempt being made.

Table of the Boiling Point of sundry Liquids, &c.

Ether	98°	Phosphorus	554°
Aqua ammonia	140	Oil turpentine	560
Alcohol	176	Sulphur	570
Water	212	Sulphuric Acid	590
Muriate of lime	230	Linseed oil	600
Nitric acid	248	Mercury	660

Table of the quantity of real Acid taken up by Alkalies and Earths.—By Mr. Kirwan.

100 Parts.	Sulphuric.	Nitric.	Muriatic.	Carbonic.
Potash	82,48	84,96	56,30	105
Soda	127,68	135,71	73,41	66,80
Ammonia	383,80	247,82	171	Variable
Barytes	50	56	31,80	282
Strontian	72,41	85,56	46	43,20
Lime	143	179,50	84,49	81,81
Magnesia	172,64	210	111,35	200
Alumine	150,90	. .	. .	335

Table of the Quantity of Alkalies and Earths taken up by 100 Parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, when saturated.—By Mr. Kirwan.

100 Parts.	Potash	Soda.	Ammo.	Barytes.	Stron.	Lime.	Magnesia.
Sulphuric	121,48	78,32	26,05	200	138	70	57,92
Nitric	117,70	73,03	40,35	178,12	116,86	55,70	47,64
Muriatic	177,60	136,20	58,48	314,46	216,21	118,30	898
Carbonic	95,10	149,60	. .	354,50	231	122	50

Table of the component Parts of Salts.—By Mr. Kirwan.

Salts.	Baſis.	Acid.	Water.	State.
Pearl aſh . .	60	30	6	Dry
Carbonate of potaſh .	41	43	16	Cryſtallized
—— ſoda .	21,58	14,42	64	Fully cryſtallized
—— ſoda .	59,86	40,05	. .	Deficcated
—— barytes .	78	22	. .	Natural
—— ſtrontian .	69,5	30	. .	Natural
—— lime . .	55	45	. .	Natural and pure
—— magneſia .	25	50	25	Cryſtallized
—— common do. .	45	34	21	Dried at 80°
Sulphate of potaſh .	54,08	45,02	. .	Dry
—— ſoda .	18,48	23,52	58	Fully cryſtallized
—— ſoda .	44	56	. .	Deficcated at 700°
—— ammonia .	14,24	54,66	31,1	
—— barytes .	66,66	33,33		Natural
—— ſtrontian .	58	42	.	Natural
—— lime .	32	46	22	Dried at 66°
—— lime .	35,23	50,39	14,38	Dried at 170°
—— lime .	38,81	55,84	5,35	Ignited
—— lime .	41	59	. .	Incandeſcent
—— magneſia .	17	29,35	53,65	Fully cryſtallized
—— magneſia .	36,68	63,32	. .	Deficcated
Alum . .	31,24 & wat.	17,66	51	Cryſtallized
Alum . .	63,75	36,25	. .	Deficcated at 700°
Nitrate of potaſh .	51,8	44	4,2	Dried at 70°
—— ſoda .	40,58	53,21	6,21	Dried at 400°
—— ſoda .	42,34	57,55	. .	Ignited
—— ammonia .	23	57	20	
—— barytes .	57	32	11	Cryſtallized
—— ſtrontian .	36,21	31,07	32,72	Cryſtallized
—— lime .	32	57,44	10,56	Well dried in air
—— magneſia .	22	46	22	Cryſtallized
Muriate of potaſh .	64	36	. .	Dried at 80°
—— ſoda .	53	47 & wat.	. .	Dried at 80°
—— ammonia .	. .	. .	. .	Cryſtallized
—— ammonia .	25	42,75	32,25	Sublimed
—— barytes .	64	20	16	Cryſtallized
—— barytes .	76,2	23,8	. .	Deficcated
—— ſtrontian .	40	18	42	Cryſtallized
—— ſtrontian .	69	31	. .	Deficcated
—— lime .	50	42	8	Red hot
—— magneſia .	31,07	34,59	34,34	Senſibly dry

A TABLE of the PROPERTIES of several of the SALTS, arranged in each class according to the Affinities of their Radicals for the Acids.

Salts.	Origin.	Taste.	Form of their Crystals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water. 60°	Boiling.
Sulphate of barytes	Native	None		None	Decrepitates	Insoluble	Insoluble
——— potash	Artificial	Bitter and acrid	Six-sided prisms	Ditto	Ditto	6	20
——— ditto super	Ditto	Sharp and hot	Ditto	Little	Fusible	50	100
——— soda	In sea water	Bitter and cool	Ditto grooved	Effloresces	Aqueous fusion	20	45
——— strontian	Native	None	Needles intersecting each other	None	Fusible at a high temperature	Insoluble	Insoluble
——— lime	Ditto	Hardly perceptible	Quadrangular prisms	Ditto	Calcines and melts	Nearly inso.	Nearly inso.
——— ammonia	Artificial		Six-sided prisms	Little	Aqueous fusion	50	50 little more
——— magnesia	In sea water	Bitter and cool	Four-sided ditto, ending in pyramids	Slightly efflorescent	Ditto	100	133
——— ditto and ammonia	Artificial	Ditto and acrid	Octahedrons	None	Ditto	Little solu.	Little soluble
——— alumine super	Ditto	Astringent	Thin pearly crystals	Little	Dries to powder	Moderately	Moderately
——— ditto and potash	Ditto	Ditto and styptic	Octahedrons	Ditto	Melts and dries	5	75
Sulphite of barytes	Ditto	Little	Tetrahedrons	Ditto		Insoluble	Insoluble
——— lime	Ditto	Sulphureous	Six sided prisms	Effloresces	Dries to powder	$\frac{1}{8}$th of a part	
——— potash	Ditto	Ditto sharp and acrid	Various	Ditto	Decrepitates	100	Still more
——— soda	Ditto	Ditto and cool	Four-sided prisms	Ditto	Watery fusion	25	100
——— ammonia	Ditto	Cool	Six-sided ditto, and various	Deliquesces	Decrepitates	100	
——— magnesia	Ditto	Sweet and earth	Flat transparent tetrahedrons	Effloresces	Softens and dries	5	
——— alumine	Ditto	Sulphureous and earthy	In white powder	Changes to sulphate	Decomposes	Insoluble	Insoluble

65. Take the transparent liquid produced in the last experiment, and give it heat. The earth will now be precipitated in the state of CARBONATE OF LIME as before.

66. Pour a little clear lime water into a wine glass, and a little clear solution of carbonate of potash into another glass. When these two transparent fluids are thrown together, an abundant precipitate of CARBONATE OF LIME will be the consequence.

67. Proceed as in the last experiment, but instead of carbonate of potash, pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate of CARBONATE OF MAGNESIA, and SULPHATE OF LIME will be produced.

68. For another experiment take in the same manner, separately, lime water, and a solution of allum. The union of these solutions will produce a mixed precipitate of ALUMINE and SULPHATE OF LIME.

69. If a strong solution of caustic potash, and a saturated solution of Epsom salt be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of MAGNESIA and SULPHATE OF POTASH.

70. To a glass of water, suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a SPARKLING APPEARANCE on the sides of the glass and surface of the fluid.

71. Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived: pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of SULPHATE OF BARYTES will be produced.

72. Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of barytes, use *nitrate of lead.* In this case SULPHATE OF LEAD will be precipitated.

73. Prepare two glasses of rain water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of silver* into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of SULPHATE OF SILVER will appear.

74. Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid.* Proceed as before, and a precipitate of MURIATE OF SILVER will be produced.

75. Take two glasses, as in experiment 73, and into one of them put a drop of sulphuric acid, and a drop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a MIXED precipitate will be produced, consisting of MURIATE OF SILVER, and SULPHATE OF SILVER.

76. Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be re-dissolved, and the muriate of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of SEPARATING these METALLIC SALTS whenever they occur in a state of mixture.

77. Mix one ounce of litharge of lead with one drachm of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true MURIATE OF LEAD of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called PATENT YELLOW.

78. Take one ounce of red lead, and half a drachm of charcoal in powder; incorporate them well in a mortar, and then fill the bowl of a tobacco pipe with the mixture. Submit it to an intense heat in a common fire, and, when melted, pour it out upon a slab. The result will be METALLIC LEAD completely revived.

79. Take a little *red-lead*, submit it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the VITRIFICATION OF METALS.

80. Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of *carbonate* of *potash*. If a piece of white cloth be dipped in this mixture, it will come out a BLUE. If a piece of yellow cloth be dipped in it, it will become a GREEN, or a red will be converted to a PURPLE. A slip of blue litmus paper immersed in it will immediately become RED.

81. If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the colouring matter will be rendered INSOLUBLE AND IMMEDIATELY PRECIPITATE, combined with the alumine, the base of this salt.

82. Boil a little cochineal in water with a grain or two of cream of tartar, (super tartrate of potash) and a dull kind of crimson solution will be formed. By the addition of a few drops of nitro-muriate of tin, the colouring matter will be PRECIPITATED OF A BEAUTIFUL SCARLET. This, and some of the former instances, will give the student a tolerably correct idea of the general processes of dying woollen cloths.

83. If a few strips of dyed linen cloth, of different colours, be dipped into a phial of oxygenized muriatic acid, the colours will be quickly discharged; there are few colours at least that can resist the operation of this acid. This experiment may be considered an example of the process of BLEACHING coloured goods.

84. Having found a piece of blue linen cloth, that will bleach in oxygenized muriatic acid, dip the tip of the finger in a solution of *muriate of tin*, and press it while wet with the solution, upon a strip of this cloth. After an interval of a few minutes immerse the cloth in the phial of oxygenized muriatic acid, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin has preserved its ORIGINAL COLOUR, while the rest of the cloth will have become WHITE.

85. Add to a solution of carbonate of potash an equal quantity by weight of nitrate of iron, and apply it to a piece of calico: it will produce a PERMANENT COLOUR, viz. the *buff* of the calico printers.

86. To an ounce of arnotto add an ounce of the potash of commerce, and boil these in water till perfectly dissolved. This will produce the PALE REDDISH BUFF so much in use, and sold under the name of NANKEEN DYE.

87. If muriate of tin, newly made, be added to a solution of indigo in sulphuric acid, the oxygen of the indigo will be absorbed, and the solution instantly converted to a *green*. It is on the same principle that muriate of tin is employed in cleansing discoloured leather furniture; as it absorbs the oxygen, and the LEATHER IS RESTORED TO ITS NATURAL COLOUR.

88. Take a piece of very dark brown linen that has been dyed with fustic, and spot it in several places with a *colourless* solution of muriate of tin. Wherever the cloth has been touched with this solution, the original colour will be discharged, and SPOTS OF A BRIGHT YELLOW will appear in its stead.

89. If lemon juice be dropped upon any kind of slate, buff, or yellow colour, the dye will instantly be discharged. It is by this method that calico printers give the WHITE SPOTS OR FIGURES TO PIECE-GOODS. The crystallized acid in a state of solution is generally used for this purpose. These few experiments will give the student some idea of the nature of calico printing.

90. Take a slip of blue litmus paper, and dip it into acetous acid: this will immediately change it to a red. It is so delicate a test, that according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its ORIGINAL BLUE COLOUR.

91. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than 1-2200th part of the water. The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, which restore its ORIGINAL YELLOW.

92. Write upon paper with a diluted solution of muriate of copper; when dry it will not be visible, but on being warmed before the fire the writing will become of a beautiful YELLOW.

93. Write with a solution of muriate of cobalt. The writing, while dry, will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant GREEN colour.

94. Write with acetate of cobalt, or with a muriate of cobalt previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored of a beautiful BLUE.

95. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in experiment No. 93, and the flowers, some with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape, or winter scene; but when gently warmed, the trees and flowers will be DISPLAYED IN THEIR NATURAL COLOURS, which they will preserve only while they continue warm. This may be often repeated.

96. Write with dilute nitrate of silver. When dry it will be entirely invisible. Hold the paper over a vessel containing sulphuret of ammonia. The writing now will appear very distinct, and the letters will shine with the METALLIC BRILLIANCY OF SILVER.

97. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter, with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing by means of the glass stopper, within the decanter. By an attention to the paper the WRITING WILL BECOME VISIBLE by degrees, as the gas rises from the bottom of the vessel.

98. Write with a weak solution of sulphate of iron; let i[illegible] it will be invisible. By dipping a feather in tincture of galls an[illegible] wet feather over the letters, the writing will be REST[illegible] pear BLACK.

99. Write with a similar solution, and when dry wash the letters in the same way with prussiate of potash, and they will be restored of a BEAUTIFUL BLUE.

100. Write with a solution of sulphate of copper, wash as before with prussiate of potash, and the writing will be revived of a REDDISH BROWN colour.

101. Procure a glass jar, such as is generally used for deflagrating the gases, and fill it with oxygenized muriatic acid gas. If nickel, arsenic, or bismuth in powder be thrown into this gas, the metal will inflame, and continue to burn with the most BRILLIANT COMBUSTION. See page 131.

102. Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of SUBLIMATION.

103. Fill a glass tumbler half full of lime water; then breathe into it frequently *with the mouth open*; at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and, if suffered to remain at rest, REAL CHALK will be deposited, as at No. 63.

104. Mix a little acetate of lead, with an equal portion of sulphate of zinc; let them be mixed with the utmost care, still no chymical change will be perceptible; but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a FLUID WILL BE PRODUCED. If alum or Glauber salt be used instead of the sulphate of zinc, the experiment will equally succeed.

105. If the leaves of a plant, fresh gathered, be placed in the sun as directed, page 95, very pure OXYGEN GAS may be collected.

106. Put a little fresh calcined magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sulphuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be COMPLETELY IGNITED.

107. If the student be in possession of an air pump, the following experiment may easily be performed: Let him fix a small jar of *ether* within a vessel containing a little water, and place both under the receiver of the air-pump, as directed page 47. The exhaustion of the receiver will cause one of the fluids to BOIL, and the other to FREEZE AT THE SAME INSTANT.

108. If a few pounds of a mixture of iron filings and sulphur be made into a paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that COMBUSTION AND FLAME will be the consequence.

109. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of WATER BY COMBUSTION.

110. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if a little solution of caustic potass be added, and the phial be then shaken, an intimate combination of the materials will [illegible] ed by the disposing affinity of the alkali, and a perfect SOAP pro-

111. Put a little common sulphur into an iron dish, place it under a jar of oxygen gas, and set fire to it as directed page 123, and sulphuric acid will be formed. This is an example of the formation of an ACID BY COMBUSTION.

112 Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the DECOMPOSITION OF AN ACID.

113. Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of METALLIC REVIVIFICATION.

114. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire; a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a METALLIC TREE.

115. Fill a small glass matras, or flask, holding about half a pint, with any kind of coloured water, having previously put in a few tea-spoonfuls of *ether*: then invert the flask in a shallow vessel of water, and pour by degrees boiling water upon its bulb. By the sudden accession of heat the ether will be changed into vapour; which will force out the coloured water, and fill the whole of the vessel. This experiment will afford an example of a liquid being converted into an ELASTIC VAPOUR BY CALORIC.

116. For want of a proper glass vessel, a table spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ETHER WILL EXPAND, and the bladder become inflated.

117. Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red hot, remove them from the fire, and, when cold, the carbonic acid of the chalk will have been decomposed, and the BLACK CHARCOAL, the basis of the acid, may be easily perceived amongst the materials.

118. Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas, and pour it out upon the jar containing the taper. This being an *invisible* gas, the operator will appear to invert merely an *empty* vessel, though the taper will inevitably be EXTINGUISHED immediately.

119. Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured upon it, COMBUSTION AND INFLAMMATION will immediately ensue.

120. If strong nitrous acid be poured upon a small quantity of a mixture of oxygenized muriate of potash and phosphorus, FLASHES OF FIRE will be emitted at intervals for a considerable time.

121. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, LIGHT WILL BE EVOLVED sufficient to show the hour upon a watch.

122. Let sulphuric acid be poured into a saucer upon some acetate of potash. Into another saucer put a mixture of about two parts quick lime, and one of sal ammoniac, both in powder, adding to these a *very small* quantity of boiling water. Both saucers while separate will yield *invisibl* but the moment they are brought close together, the operator will LOPED IN VERY VISIBLE VAPOURS. Muriate of so periment, may be substituted for acetate of potash.

123. Take a glass tube with a bulb in form of a common thermometer; fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will presently be FROZEN, EVEN IN SUMMER.

124. Procure a phial with a glass stopper accurately ground into it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its COLOUR, which it will RECOVER ONLY BY THE RE-ADMISSION OF AIR. These effects may thus be repeatedly produced.

125. Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a bason of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel; affording an example of SIMPLE SUBLIMATION.

126. Pour concentrated nitric acid upon pieces of iron, and very little action will be seen: but if a few drops of *water* be added a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect SOLUTION OF THE METAL effected.

127. Take any solution of iron, a chalybeate water for instance, and add a little succinate of ammonia: a precipitate of iron will immediately be visible. By the use of this test the QUANTITY of iron in any solution may be ACCURATELY ASCERTAINED.

128. In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned. This is an effectual mode of DETECTING THIS PERNICIOUS METAL.

129. Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, LIGHT WILL BE EXTRICATED.

130. Dissolve some quicksilver in nitrous acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the PRECIPITATION OF ONE METAL BY ANOTHER.

131. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, the gold will be precipitated of a purple colour, forming that beautiful pigment, called POWDER OF CASSIUS.

132. Take a phial with solution of sulphate of zinc, and another containing a little aqua ammonia, both transparent fluids. By mixing them, a curious phænomenon may be perceived. The zinc will immediately be precipitated in a white mass, and, if then shaken, almost as INSTANTLY REDISSOLVED.

133. If a colourless solution of galls be added to a solution of bismuth in nitric acid, equally colourless, a *brown* precipitate will be produced. This is a distinguishing CHARACTERISTIC OF THIS METAL.

134. If a colourless solution of arsenic in nitric acid be poured into a co-
rless solution of copper, a *green* precipitate will be produced, forming an
niate of copper similar to an ore found in the Cornish mines. These
als may thus be RECIPROCALLY DETECTED.

135. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful GREEN FLAME.

136. If alcohol be inflamed in like manner with a little strontian in powder, or any of its salts, the mixture will give a PURPLE FLAME.

137. If barytes be used instead of strontian, we shall have a brilliant YELLOW FLAME.

138. Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the FIXITY of the NOBLE METALS.

139. Fuse a given quantity of nitre in a crucible, and when in complete fusion throw pulverized coal into it, by small quantities at a time. The carbonaceous matter will decompose the nitre, and the bituminous part will burn away without acting upon it. This experiment will exhibit a mode of ANALYSING COAL; for every 100 grains of nitre that are decomposed in this way, bespeak ten grains of carbon.

140. Burn a piece of iron wire in a deflagrating jar of oxygen gas, as directed page 241, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time, and afterwards phosphorus will burn in it in like manner. An experiment to show the RELATIVE COMBUSTIBILITY of different substances.

141. If oxide of cobalt be dissolved in ammonia, a RED SOLUTION will be produced, different in colour from that of all other metallic oxides.

142. If nickel be dissolved in nitric acid, a beautiful GREEN SOLUTION will be formed. The oxide of this metal is used to give a delicate grass green to porcelain.

143. If colourless prussiate of potash be added to a solution of titanium, this metal also will be precipitated of a GREEN COLOUR.

144. Add a little colourless solution of galls to a clear solution of antimony in nitro-muriatic acid, and the metal will be precipitated of a PALE YELLOW COLOUR.

145. If a solution of tungstate of potash be poured into a solution of the green sulphate of iron, a YELLOW PRECIPITATE will fall down. By this experiment the distinguishing characteristic of this metal is exhibited.

146. Add a few grains of oxygenized muriate of potash to a tea-spoonful or two of alcohol, drop one or two drops of sulphuric acid upon the mixture, and the whole will BURST INTO FLAME, forming a very beautiful appearance.

147. Into an ale glass of water put a few filings of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 34, and phosphuretted hydrogen will presently be disengaged, which will INFLAME on rising to the SURFACE OF THE WATER.

148. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the PHOSPHORUS ON FIRE.

149. If hot water be poured into a glass jar of cold water, it will remain on the *surface*; but if cold water be poured upon hot water it will sink to the *bottom* of the vessel. This experiment may be rendered more obvious by

colouring that portion of the water which is poured in. The design of this is to show the CHANGE of the SPECIFIC GRAVITY of the same body, merely, by the AGENCY OF CALORIC.

150. If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the metal will immediately be precipitated. In this state it is often employed in GILDING CHINA.

151. If flowers or any other figures be drawn upon a ribband or silk, with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures firmly fixed upon the silk, will become visible, and shine with METALLIC BRILLIANCY.

152. By proceeding in the same manner, and using a solution of gold in nitro-muriatic acid, silks may be PERMANENTLY GILT at a most insignificant expense; and will exhibit an appearance the most beautiful that can be conceived.

153. To a similar solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate: the upper stratum, or ethereal gold, is then to be carefully poured off into another vessel. If any polished steel instrument or utensil be dipped into this solution, and instantly plunged into water; the surface will have acquired a coat of pure gold, being a very elegant and economical mode of PRESERVING POLISHED STEEL FROM RUST.

154. If nitro-muriate of platina be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platina may be decanted as in the preceding experiment. Polished brass, and some other metals immersed in this solution, will be COVERED WITH A COAT OF PLATINA. This process may be applied to many useful purposes.

To read or practise the foregoing experiments merely for the sake of amusement, may occasionally have its advantages; but a resolution to repeat them, and examine all the phenomena, for the sole purpose of receiving instruction, is what the author would principally inculcate. Let it never be forgotton, that *no effect*, however extraordinary, or even trivial, it may appear to us, can ever happen but in consequence of some previously established law of unnerring nature. The following apostrophe of Dr. Darwin to the Fountain of all Goodness, may possibly tend to impress this important truth upon the student's mind:—

> Thus at thy potent nod, *effect* and *cause*
> Walk hand in hand, accordant to thy laws;
> Rise at Volition's call, in groups combin'd,
> Amuse, delight, instruct and serve mankind.

A VOCABULARY

OF

CHYMICAL TERMS.

ACETATES. Salts formed by the acetic acid.

ACIDS *mineral*, are formed of certain mineral ſubſtances called acidifiable radicals, combined with oxygen.

—— *vegetable*, are compoſed of carbon, hydrogen, and oxygen, in various proportions.

—— *animal*, are compoſed of the above three ſimple ſubſtances, in various proportions with the addition of nitrogen.

—— *oxygenated* or *oxygenized*. Acids combined with an additional quantity of oxygen, for particular purpoſes. The oxygenized muriatic acid uſed in bleaching is an inſtance of this ſuper-oxygenizement.

—— *hyperoxygenized*. Acids which are oxygenized to a maximum.

ACIDULES. A term applied to the natural combination of ſome acids with a portion of potaſh. The oxalic acid and the tartaric are the only acids that have hitherto been found in this ſtate of ſemi-ſaturation.

AERIFORM *fluids*. Fluid ſubſtances combined with an additional portion of caloric ſufficient to give them the gaſeous form.

AFFINITY. A term uſed to expreſs that peculiar propenſity which *different* ſpecies of matter have to unite with each other, or with portions of matter of their own ſpecies.

—— *of aggregation*. A force by which two bodies of the *ſame* kind tend to unite, and by which an aggregate is formed without the *chymical* properties of the ſubſtances being at all changed.

—— *of compoſition*. A force by which ſubſtances of *different* kinds unite, and by which matter is formed whoſe properties are different from thoſe of the bodies before their combination. This attraction is ſtronger in proportion as the nature of the bodies is different, between which it is exerted.

AGGREGATES. Subſtances whoſe parts are united by coheſive, and not by chymical attraction. See *Affinity of aggregation*.

ALBUMEN. The modern name for coagulable lymph. It is that peculiar animal ſubſtance which forms the ſerum of the blood, the white of eggs, and other compounds.

ALCOHOL. Rectified ſpirit of wine. When good, its ſpecific gravit

ALEMBIC. The term formerly given to the ſtill uſed by chymiſts f tions.

ALKALIES. Peculiar ſubſtances which have an urinous, burning, and cauſtic taſte, and a ſtron tendency to combination. When united with acids they form mild alkaline ſalts. See page 108.

ALLOYS. A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with ſilver or copper, for the purpoſes of coinage.

ALLUVIAL. By alluvial depoſitions is meant the ſoil which has been formed by the deſtruction of the mountains, and the waſhing down of their particles by torrents of water.

AMALGAM. A combination or mixture of mercury with any other metal, is called an amalgam.

AMMONIACAL *ſalts*. Salts formed with ammonia, or volatile alkali.

AMYLACEOUS. A term applied to thoſe vegetable ſubſtances which contain ſtarch.

ANALYSIS. The reſolution of a ſubſtance into its conſtituent parts, for the purpoſe of examination.

ANNEALING. The art of rendering ſubſtances tough which are naturally hard and brittle. Glaſs and iron are annealed by gradual cooling; braſs and copper by heating, and then ſuddenly plunging them in cold water.

APPARATUS *chymical*. This term is deſcriptive of all the utenſils made uſe of in a chymical laboratory. The principal are ſtills, furnaces, crucibles, retorts, receivers, matraſſes, worm tubs, pneumatic troughs, thermometers, &c.

AREOMETER. A graduated glaſs inſtrument with a bulb, by which the ſpecific gravity of liquids is aſcertained. Baumé's areometer is that which is chiefly referred to when the French writers ſpeak of this inſtrument.

ARGILLACEOUS. A term deſcriptive of thoſe earths which contain alumine or clay.

AROMA. A term uſed for the odour which ariſes from certain vegetables, or their infuſions.

ARSENIATES. Salts formed by the acid of arſenic.

ATMOSPHERES. We uſe this term to expreſs the degree of additional preſſure given to fluids. Thus, if in order to impregnate water with any of the gaſes, I give it a preſſure of 15lbs. upon every ſquare inch of ſurface, I am ſaid to give it *one* atmoſphere; if 30lbs. *two* atmoſpheres, &c. &c.

ATTRACTION. Chymical attraction is a term ſynonymous with *affinity*; which ſee.

AURUM-MUSIVUM. A combination of tin and ſulphur. It is alſo called muſive gold, and moſaic gold.

AZOTE. A peculiar ſimple ſubſtance, ſynonymous with nitrogen. It enters into a variety of compounds, and forms more than three parts in four of atmoſpheric air. See page 55.

AZOTIC *gas*. Azote or nitrogen rendered gaſeous by caloric.

B.

BALLOON. A term given by the French to their ſpherical chymical receivers.

BALSAMS. Certain aromatic reſinous ſubſtances, which are obtained from ſome trees by inciſions. Of this kind are the Canada balſam, the balſam of Copaiva, the balſam of Tolu, &c.

BAROMETER. An inſtrument which ſhows the variation of the preſſure of the atmoſphere, by the riſe or fall of a column of mercury in a graduated glaſs tube.

BASE. A chymical term, uſually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a ſalt.

BATHS. Veſſels for diſtillation or digeſtion, contrived to tranſmit heat gradually and regularly.

—— *ſand*. Veſſels filled in part with dry ſand, in which thoſe retorts are placed which require a greater heat than can be given by boiling water. In large works iron plates are uſed inſtead of veſſels of capacity. They are often called *ſand heats*.

—— *water*. Veſſels of boiling water, in which other veſſels containing the matters to be diſtilled or digeſted are placed, in order that the ſame heat may be kept up throughout the whole of any particular proceſs.

[illegible]ATES. Salts formed by the benzoic acid.

BITTERN. The mother-liquor which remains after the cryſtallization of muriate of ſoda (ſea ſalt). It generally contains ſulphate of magneſia, and a ſmall portion of ſulphate of ſoda.

BITUMEN. A generic term, applied to a variety of foſſil inflammable ſubſtances.

BLOW-PIPE. An inſtrument to increaſe and direct the flame of a lamp for the analyſis of minerals, and for other chymical purpoſes.

BOLT-HEAD. A round chymical veſſel with a long neck, uſually employed for digeſtions. It is alſo called a matraſs.

BOMBATES. Salts formed by the bombic acid.

BORATES. Salts formed with the acid of borax.

BUTTON. A name given to the ſmall round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced for experiment.

C.

CALCAREOUS. A chymical term formerly applied to deſcribe chalk, marble, and all other combinations of lime with carbonic acid.

CALCINATION. The application of heat to ſaline, metallic, or other ſubſtances; ſo regulated as to deprive them of moiſture, &c. and yet preſerve them in a pulverulent form.

CALORIC. The chymical term for the matter of heat.

——— *free.* Is caloric in a ſeparate ſtate, or, if attached to other ſubſtances, not *chymically* united with them.

——— *latent.* Is the term made uſe of to expreſs that portion of caloric which is chymically united to any ſubſtance, ſo as to become a *part* of the ſaid ſubſtance.

CALORIMETER. An inſtrument for aſcertaining the quantity of caloric diſengaged from any ſubſtance that may be the object of experiment.

CALX. An old term made uſe of to deſcribe a metallic oxide.

CAMPHORATES. Salts formed by the camphoric acid.

CAPILLARY. A term uſually applied to the riſe of the ſap in vegetables, or the riſe of any fluid in very ſmall tubes; owing to a peculiar kind of attraction, called capillary attraction.

CAPSULES. Are ſmall ſaucers of clay for roaſting ſamples of ores, and for ſmelting them to aſcertain their value.

CAPUT-MORTUUM. A term ſignifying *dead-head*, being that which remains in a retort after diſtillation to dryneſs.

CARBON. The baſis of charcoal. See page 178.

CARBONATES. Salts formed by the carbonic acid.

CARBURETS. Compound ſubſtances, of which carbon forms one of the conſtituent parts. Thus plumbago, which is compoſed of carbon and iron, is called carburet of iron.

CAUSTIC *common.* Soda or potaſh deprived of its carbonic acid, and fuſed, ſometimes with the addition of lime, into a ſolid ſubſtance.

——— *lunar.* Nitrate of ſilver evaporated to dryneſs, and fuſed in a crucible. A ſolution of this ſalt is uſed by chymiſts as a teſt for muriatic acid.

CAUSTICITY. That quality in certain ſubſtances by which they burn or corrode animal bodies to which they are applied. It is beſt explained by the doctrine of chymical affinity. See page 109.

CEMENTATION. A proceſs by which metals are purified or changed in their qualities by heat, without fuſion, by means of a compoſition, called a cement, with which they are covered. Thus iron, by being kept a long time in a certain degree of heat, ſurrounded by charcoal powder, is converted into ſteel.

CHALYBEATE. A term deſcriptive of thoſe mineral waters which are impregnated with iron. See *Martial.*

CHARCOAL. Wood burnt in cloſe veſſels: it is an oxide of carbon, and generally contains a ſmall portion of ſalts and earth. Its carbonaceous matter may be converted by combuſtion into carbonic acid gas.

CHATOYANT. A term much uſed lately by the French chymiſts to deſcribe a property in ſome metallic and other ſubſtances, of varying their colours according

to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.

CHERT. A term made use of in describing a species of siliceous stones, which are coarser and softer than the common silex. It is often found in large masses in quarries of limestone.

CHROMATES. Salts formed by the chromic acid.

CITRATES. Salts formed by the citric acid.

COAL. A term applied to the residuum of any dry distillation of animal or vegetable matters.

COHESION. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity*.

COHOBATION. When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. It is not much practised by modern chymists.

COLUMBATES. Salts formed with the columbic acid.

COMBINATION. A term expressive of a true *chymical* union of two or more substances; in opposition to mere mechanical mixture.

COMBUSTIBLES. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chymists into simple and compound combustibles.

COMBUSTION. The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by the French writers to signify the opposite operation.

COMMINUTION. The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.

CONCENTRATION. The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

CONDENSATION. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

CRUCIBLES. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

CRYSTALLIZATION. An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures.

——————— *water, of*. That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances.

CUPEL. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

DECOMBUSTION. Synonymous with deoxidation; which see.

DECOMPOSITION. The separation of the constituent principles of compound bodies by chymical means.

DECREPITATION. The sudden decomposition of salts, attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

DEFLAGRATION. The act of burning two or more substances together, as charcoal and nitre, or nitre and sulphur.

DELITE. A term used by some of the French writers, signifying to break, by the action of the air, like a soft stone into layers. See Annales de Chimie, tom. xix. 79.

DELIQUESCENCE *of solid saline bodies*, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid.

DELIQUIUM. Is the state of potash, or any deliquescent salt, when it has so far deliqu[illegible] exposure to the air as to have become a liquid.

DEOXID[illegible] [illegible]EOXIDIZE. To deprive a body of oxygen.

DE-OXIDATION, or DIS-OXIDATION. A term made uſe of by ſome writers to expreſs that operation by which one ſubſtance deprives another ſubſtance of its oxygen. It is called unburning a body by the French chymiſts. *De-oxidizement* is a better term.

DEPHLEGMATION. Is the act of ſeparating the water from chymical liquors.

DEPHLOGISTICATED. A term which was given by Dr. Prieſtley to oxygen gas. When he firſt diſcovered this gas, he called it dephlogiſticated air.

DEPURATION. The purging or ſeparating any liquid in a ſtate of purity from its fæces or lees.

DETONATION. An exploſion with noiſe. It is moſt commonly applied to the exploſion of nitre when thrown upon heated charcoal.

DIGESTION. The effect produced by the continued ſoaking of a ſolid ſubſtance in a liquid, with the application of heat.

DIGESTOR *Papin's*. An apparatus for reducing animal or vegetable ſubſtances to a pulp or gelly expeditiouſly.

DISTILLATION. A proceſs for ſeparating the volatile parts of a ſubſtance from the more fixed, and preſerving them both in a ſtate of ſeparation.

DOCIMASTIC ART. The art of aſſaying metals.

DUCTILITY. A quality of certain bodies, in conſequence of which they may be drawn out to a certain length without fracture.

DULCIFICATION. The combination of mineral acids with alcohol. Thus we have dulcified ſpirit of nitre, dulcified ſpirit of vitriol, &c.

E.

EDULCORATION. Expreſſive of the purification of a ſubſtance by waſhing with water.

EFFERVESCENCE. An inteſtine motion which takes place in certain bodies, occaſioned by the ſudden eſcape of a gaſeous ſubſtance.

EFFLORESCENCE. A term commonly applied to thoſe ſaline cryſtals which become pulverulent on expoſure to the air, in conſequence of the loſs of a part of the water of cryſtallization.

ELASTICITY. A force in bodies, by which they endeavour to reſtore themſelves to the poſture from whence they were diſplaced by any external force. See page 43.

ELASTIC FLUIDS. A name ſometimes given to vapours and gaſes. Vapour is called an *elaſtic* fluid; gas, a *permanently* elaſtic fluid.

ELECTIVE ATTRACTIONS. A term uſed by Bergman and others to deſignate what we now expreſs by the words chymical *affinity*; which ſee. When chymiſts firſt obſerved the power which one compound ſubſtance has to decompoſe another, it was imagined that the minute particles of ſome bodies had a *preference* for ſome other particular bodies; hence this property of matter acquired the term *elective* attraction.

ELEMENTS. The ſimple, conſtituent parts of bodies, which are incapable of decompoſition; they are frequently called principles.

ELIQUATION. An operation whereby one ſubſtance is ſeparated from another by fuſion. It conſiſts in giving the maſs a degree of heat that will make the more fuſible matter flow, and not the other.

ELUTRIATION. The operation of pulverizing metallic ores or other ſubſtances, and then mixing them with water, ſo that the lighter parts which are capable of ſuſpenſion may be poured off, and thus ſeparated from the groſſer particles. The metallic ſubſtances which are reduced to an impalpable powder are prepared by this proceſs.

EMPYREUMA. A peculiar and indeſcribably diſagreeable ſmell, ariſing from the burning of animal and vegetable matter in cloſe veſſels.

EOLIPILE. A copper veſſel with a ſmall orifice, and partly filled with water. It is made hot, in order that the vapour of the water may ruſh out with violence, and carry a ſtream of air with it to increaſe the intenſity of fires. It is an inſtrument of great antiquity.

ESSENCES. What are called eſſences in chymiſtry and pharmacy are the eſſential oils obtained by diſtillation from odoriferous vegetable ſubſtances.

ESSENTIAL SALTS. The ſaline ſubſtances found in plants, and which are held

in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

ETHERS. Volatile liquids formed by the distillation of some of the acids with alcohol.

EVAPORATION. The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

EUDIOMETER. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry*.

EXPRESSION. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

EXSICCATION. The act of drying moist bodies. It is effected in two ways; by exhaling the aqueous particles by the application of heat or atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus, small matters are dried by chymists with bibulous paper; and larger masses, by spreading them on tablets of calcareous earth.

EXTRACTS. The soluble parts of vegetable substances, first dissolved in spirit or water, and then reduced to the consistence of a thick syrup, or paste, by evaporation.

F

FAT. An oily concrete animal substance, composed of oil, sebacic acid, and carbon.

FERMENTATION. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. For the changes which are effected by saccharine fermentation, see page 191.

FIBRINE. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre. Parkinson.

FILTRATION. A chymical process for the depuration of liquid substances. Bibulous paper supported by a funnel is commonly made use of; but for dear and expensive liquors chymists generally use a little carded cotton lightly pressed into the tube of a glass funnel. The valuable concentrated acids should be filtered through pounded glass.

FIXITY. A term applicable to that property of some bodies of bearing a great heat without being volatilized.

FLOWERS. In chymical language are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, and sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

FLUATES. Salts formed by the fluoric acid.

FLUIDITY. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric.

FLUX. A substance which is with metallic ores, or other bodies, to promote their fusion; as an alkali is mixed with silex, in order to form glass.

FORMATES. Salts formed by the formic acid.

FULIGINOUS. A term sometimes made use of in describing certain vapours which arise in chymical operations, having the thick appearance of smoke.

FULMINATION. Thundering, or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated.

FURNACES. Chymical vessels of various forms for the fusion of ores, or other operations which require heat.

——— *blast*. Are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

——— *wind*. Chymical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows.

FUSION. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

GALLATES. Salts formed by the gallic acid.

GALVANISM. A new science which offers a variety of phenomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body.

GANGUE. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals, in mining countries.

GAS. All solid substances when converted into permanently elastic fluids by caloric are called gases.

GASEOUS. Having the nature and properties of gas.

GASOMETER. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

GASOMETRY. The science of measuring the gases. It likewise teaches the nature and properties of these elastic fluids.

GELATINE. A chymical term for animal gelly. It exists particularly in the tendons and the skin of animals.

GLASS. Some metallic oxides when fused are called *glass*. They have somewhat of resemblance to common glass.

——— *phosphoric*. A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

——— *gall*. See *Sandiver*.

GLUTEN. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat-flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

GRADUATION. A process, by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

———. The division of a scale or measure into decimal parts.

GRAIN. The *smallest* weight made use of by chymical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

GRANULATION. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chymical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

GRAVITY. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth.

——— *specific*. This differs from absolute gravity in as much as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals. See Catechism, page 35.

GUMS. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

H.

HEAT *matter of*. See *Caloric*.

HEPAR. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potash, &c. as the case may be.

HEPATIC *gas*. The old name for the gas which is separated from sulphuret of alkali. It is now called sulphuretted hydrogen gas.

HERMETICALLY. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chymistry; hence a tube which was closed for chymical purposes, was said to be Hermetically or chymically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

HYDROGEN. A simple substance; one of the constituent parts of water.

——— *gas*. Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. It is used on this account to inflate balloons. It was formerly called inflammable air.

HYDRO-CARBONATES. Combinations of carbon with hydrogen are described

by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation.

HYDROGENIZED *sulphurets*. Certain bases combined with sulphuretted hydrogen.

HYDRO-OXIDES. Metallic oxides combined with water.

HYDROMETERS. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

HYGROMETERS. Instruments for ascertaining the degree of moisture in atmospheric air.

HYPEROXYGENIZED. A term applied to substances which are combined with the largest possible quantity of oxygen. We have muriatic acid, oxygenized muriatic acid, and hyperoxygenised muriatic acid. The latter can be exhibited only in combination.

I.

INCINERATION. The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the coasts for making mineral alkali.

INFLAMMATION. A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chymical effect.

INFUSION. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

INSOLATION. A term sometimes made use of to denote that exposure to the sun which is made in order to promote the chymical action of one substance upon another.

INTEGRANT *particles*. See chap. ix. page 169.

INTERMEDIATES. A term made use of when speaking of chymical affinity. Oil, for example, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

KALI. A genus of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes.

L.

LABORATORY. A room fitted up with apparatus for the performance of chymical operations.

LACTATES. Salts formed by the lactic acid.

LAKES. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumine, or with oxide of tin, zinc, &c.

LAMP ARGAND'S. A kind of lamp much used for chymical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

LENS. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chymists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat.

LEVIGATION. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

LIQUEFACTION. The change of a solid to the state of a fluid, occasioned by the combination of caloric.

LITHARGE. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead.

LIXIVIATION. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

LIXIVIUM. A fluid impregnated with an alkali or a salt.

LUTE. A composition for closing the junctures of chymical vessels to prevent the escape of gas or vapour in distillation.

M.

MACERATION. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

MAGISTERY. A term formerly given to most chymical precipitates, as the magistery of bismuth, &c.

MALATES. Salts formed by the malic acid.

MALLEABILITY. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric.

MARCASITE. A name given to several kinds of pyrites.

MARTIAL. An old term for chymical preparations of iron. See *Chalybeate.*

MASSICOT, A name given to the yellow oxide of lead, as minium is applied to the red oxide.

MATRASS. Another name for a bolt-head; which see.

MATRIX, or MOTHER EARTH. The stone in which metallic ores are found enveloped.

MATT. That mass of metal which separates from the scoriæ in smelting ores without previous roasting.

MENSTRUUM. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c. and spirit of wine for resins.

METALLIC OXIDES. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible sustances; and made soluble in acids.

METALLURGY. The art of extracting and purifying metals.

MINERALIZERS. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c.

MINERALOGY. The science of fossils and minerals.

MINERAL WATERS. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

MINIUM. The red oxide of lead.

MOLECULE. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chymical means.

MOLYBDATES. Salts formed with the molybdic acid.

MORDANTS. Substances which have a chymical affinity for particular colours; They are employed by dyers as a bond to unite the colour with the cloth intended to be dyed.

MOTHER-WATERS, or MOTHERS. The liquors which are left after the crystallization of any salts.

MUCILAGE. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

MUCITES. Salts formed with the mucous acid.

MUFFLE. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

MURIATES. Salts formed by the muriatic acid.

N.

NATRON. One of the names for mineral alkali, or soda.

NEUTRALIZE. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

NEUTRAL SALTS. Substances formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

NITRATES. Salts formed by the nitric acid.

NITROGEN. A term synonymous with azote; which see.

O.

OCHRES. Various combinations of the earth with oxide of iron,

OIL. A fluid substance well known. It is composed of hydrogen, oxygen, and carbon.

ORES. Metallic earths, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

OXALATES. Salts formed by the oxalic acid.

OXIDE. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

OXIDIZE. To combine oxygen without producing acidity.

OXIDIZEMENT. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity. Synonymous with oxidation.

OXYGEN. A simple substance composing the *greatest* part of water, and part of atmospheric air. (See pages 84 and 134.)

—— *gas.* Solid oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

OXYGENIZE. To acidify a substance by oxygen. Synonymous with Oxygenate.

OXYGENIZABLE. A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

OXYGENIZEMENT. The production of acidity by oxygen.

P.

PARTING. The operation of separating gold from silver by means of nitrous acid, and other mediums.

PELICAN. A glass alembic, with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of the vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

PELLICLE. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

PERCUSSION. The act of striking a body. See page 63.

PHLOGISTON. An old chymical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances.

PHOSPHATES. Salts formed with phosphoric acid.

PHOSPHITES. Salts formed with phosphorous acid.

PHOSPHURETS. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c.

PLUMBAGO. Carburet of iron, or the black-lead of commerce.

PNEUMATIC. Any thing relating to the airs and gases.

—— *trough.* A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another.

PRECIPITATE. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

PRECIPITATION. That chymical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

PRINCIPLES OF BODIES. Synonymous with *Elements*; which see.

PRUSSIATES. Salts formed with prussic acid.

PUTREFACTION. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

PYRITES. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumine and silex. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Fire-stone.

—— *martial.* That species of pyrites which contains iron for its basis. See a full account of these minerals in Henckel's Pyritologia.

PYROLIGNITES. Salts formed with the pyrolignous acid. From some late experiments it appears that the pyrolignous acid is the same as the acetous. These salts therefore are acetates.

PYROMETER. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See Philosophical Transactions, vols. lxii. and lxiv.

PYROPHORI. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See an account of a variety of experiments with these compositions in Wiegleb's Chymistry, page 622, &c.

PYROTARTRITES. Salts formed by the pyrotartarous acid; but this acid and the pyromucic are now not considered as distinct acids.

Q.

QUARTATION. A term used by refiners in a certain operation of parting. See Lewis's Com. Tech.

QUARTZ. A name given to a variety of filiceous earths, mixed with a small portion of lime or alumine. Mr. Kirwan confines the term to the *purer* kind of silex. Rock crystal and the amethyst are species of quartz.

R.

RADICALS. A chymical term for the *Elements* of bodies; which see.

——— *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound* radical. The sulphuric acid is formed with a *simple* radical; but the vegetable acids which have radicals composed of hydrogen and carbon are said to be acids with compound radicals.

REAGENTS. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See *Test.*

REALGAR. Red sulphuretted oxide of arsenic.

RECEIVERS. Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation.

RECTIFICATION. Is nothing more than the re-distilling a liquid to render it more pure, or more concentrated, by abstracting only a part.

REDUCTION. The restoration of metallic oxides to their original state of metals; which is usually effected by means of charcoal and fluxes.

REFINING. The process of separating the perfect metals from other metallic substances, by what is called cupellation.

REFRACTORY. A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

REFRIGERATORY. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm tub is a refrigeratory.

REGISTERS. Openings in chimneys, or other parts of chymical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

REGULUS. In its chymical acceptation, signifies a pure metallic substance, freed from all extraneous matters.

REPULSION. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric*, which has been called the repulsive power.

RESIDUUM. What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potash which remains in the pot after distillation of nitrous acid is called the residuum. It is sometimes called the caput mortuum.

RESINS. Vegetable juices concreted by evaporation either spontaneously or by fire. Their characteristic is solubility in alcohol, and not in water. It seems that they owe their solidity chiefly to their union with oxygen.

RETORT. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

REVERBERATORY. An oven or furnace in which the flame is confined by a dome which occasions it to be beat down upon the floor of the furnace before it passes into the chimney. Some are so contrived that it returns or reverberates upon the matter under operation.

REVIVIFICATION. See *Reduction*, which is a synonymous term: though "revivification" is generally used when speaking of quicksilver.

ROASTING. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c. with which a metal may be combined.

ROCK-CRYSTAL. Crystallized silex.

S.

SACCHARUM SATURNI. The old name for the acetate of lead.

SACCOLATES. Salts formed by the saccholactic acid.

SALIFIABLE BASES. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

SALINE. Partaking of the properties of a salt.

SALTS *neutral*. A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable base.

——— *triple*. Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potash, Rochelle salt, is an instance of this kind of combination.

SAND *bath* } See *Bath*.
——— *heat* }

SANDIVER. A matter, composed of different salts which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes. The term is probably a corruption of "Sal de verre."

SAP-COLOURS. A name given to various expressed vegetable juices of a viscid nature, which are inspissated by slow evaporation for the use of painters, &c.; sap-green, gamboge, &c. are of this class.

SAPONACEOUS. A term applied to any substance which is of the nature or appearance of soap.

SATURATION. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

SEBATES. Salts formed by the sebacic acid.

SELENITE. A salt existing in spring water, formed by sulphuric acid and lime. Its proper chymical name is Sulphate of Lime.

SEMI-METAL. A name formerly given to those metals which are neither malleable, ductile, nor fixed, if exposed to the fire. It is a term not used by modern chymists.

SILICEOUS EARTHS. A term used to describe a variety of natural substances which are composed chiefly of silex; as quartz, flint, sand, &c.

SIMPLE SUBSTANCES. Synonymous with *elements*; which see.

SMELTING. The operation of fusing ores for the purpose of separating the metals they contain, from the sulphur and arsenic with which they are mineralised, and also from other heterogeneous matter.

SOLUBILITY. A characteristic of most salts. See *Solution*.

SOLUTION. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

SPARS. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which denote the nature of each.

SPATULA. An instrument like a knife, with an elastic blade, used for mixing small quantities of powders or other substances.

SPECIFIC GRAVITY. See the word *Gravity*.

SPELTER. The commercial name of zinc.

SPIRIT. A term used by the early chymists to denote all volatile fluids collected by distillation.

SPIRIT PROOF. A term made use of to describe such ardent spirits as are of the same strength as the brandy of commerce, or of the specific gravity of 0.930, water being 1.000.

STALACTITES. Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water, through the crevices, charged with this kind of earth.

STEATITES. A kind of stone composed of silex, iron, and magnesia. Also called French chalk, Spanish chalk, and soap-rock.

STRATIFICATION. A chymical operation by which bodies are placed in a condition to act mutually upon each other by being arranged layer by layer, stratum super stratum, as is practised by metallurgists.

SUB-SALTS. Salts with less acid than is sufficient to neutralize their radicals.

SUBERATES. Salts formed with the suberic acid.

SUBLIMATE. A name given to several mercurial preparations.

SUBLIMATION. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process. See *Flowers*.

SUCCINATES. Salts formed by the succinic acid.
SUGAR. A well known substance, found in a variety of vegetables, composed of oxygen, hydrogen, and carbon.
SULPHATES. Salts formed with the sulphuric acid.
SULPHITES. Salts formed with the sulphurous acid.
SULPHURES, or SULPHURETS. Combinations of alkalies, or metals, with sulphur.
SULPHURETTED. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say Sulphuretted hydrogen, &c.
SUPER-SALTS. Salts with an excess of acid, as the super tartrate of potash.
SYNTHESIS. When a body is examined by *dividing* it into its component parts, it is called analysis; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.
SYPHON. A bent tube used by chymists for drawing liquids from one vessel into another. It is sometimes called a Crane.

T.

TARTRATES. Salts formed with the acid of tartar.
TEMPERATURE. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body.
TENACITY. Is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another.
TEST. That part of a cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition. See *Re-agent.*
TEST-PAPERS. Papers impregnated with certain chymical re-agents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.
THERMOMETER. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. (See page 68). Other thermometers are used in different parts of Europe. For the difference in the scale of these thermometers, see the Table at the end of this volume.
TINCAL. The commercial name of crude borax.
TINCTURES. Solutions of substances in spirituous menstrua.
TORREFACTION. An operation similar to roasting; which see.
TRANSMUTATION. A favorite term among the old chymists, signifying the changing of one metal to another, which they supposed possible.
TRITORIUM. A vessel used for the separation of two fluids which are of different densities. But the same operation may be performed by a common funnel.
TRITURATION. A chymical operation whereby substances are united by friction. Amalgams are made by this method.
TUBULATED. Retorts which have a hole at the top for inserting the materials to be operated upon, without taking them out of the sand heat, are called tubulated retorts.
TUNGSTATES. Salts formed by the tungstic acid.
TUTENAG. An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

V.

VACUUM. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chymical or philosophical means.
VAPOUR. This term is used by chymists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.
VATS. Large chymical vessels, generally of wood, for making infusions, &c.
VITAL AIR. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestley.
VITRIFICATION. When solid substances have undergone very intense heats, so as to be fused thereby, they frequently have an appearance resem[illegible] They are then said to be vitrified, or to have undergone vitrificati[illegible]

VITRIOLS. A class of substances, either earthy or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

VITRIOLATED TARTAR. The old name for sulphate of potash.

VOLATILE ALKALI. The old name for ammonia.

VOLATILE SALTS. The commercial name for carbonate of ammonia.

VOLATILITY. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

VOLUME. A term made use of by modern chymists to express the space occupied by gaseous or other bodies.

U.

UNION *chymical*. When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chymical* union.

USTULATION. The roasting of ores, to separate the arsenic and sulphur which mineralizes the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation is called ustulation.

W.

WADD. The name given by miners to plumbago, or carburet of iron, known in commerce by the very improper name of *black-lead*.

WADD-*black*. The miners' name for the argillaceous ore of manganese.

WATER. The most common of all fluids, composed of 85 parts of oxygen and 15 of hydrogen. See page 86.

—— *mineral*. Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

WAY *dry*. A term used by chymical writers when treating of analysis or decomposition. By decomposing in the dry-way, is meant, by the agency of fire.

WAY *humid*. A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water, and chymical re-agents, or tests.

WELDING-HEAT. That degree of heat in which two pieces of iron or of platina may be united by hammering.

WHITING. Carbonate of lime or chalk, cleared of its grosser impurities by washing, and made up into balls for sale. It is sold in the shops by this name.

WOLFRAM. An ore of tungsten containing also manganese and iron.

WORM-TUB. A chymical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation. See *Refrigeratory*.

WOULFE's *apparatus*. A contrivance for distilling the mineral acids and other gaseous substances with little loss; being a train of receivers with safety pipes, and connected together by tubes. For a full description of this most useful apparatus, see Philosophical Transactions for 1767.

Z.

ZAFFRE. An oxide of cobalt, mixed with a portion of siliceous matter. It is imported in this state from Saxony.

ZERO. The point from which the scale of a thermometer is graduated. Thus Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt. See Notes, page 68.

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